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CYCLOPÆDIA:

OR, A NEW

UNIVERSAL DICTIONARY

OF

ARTS and SCIENCES.

Cements and Lutes

CEMENTS and LUTES. Under this article may be mentioned the receipts for preparing some of the most useful substances of this kind, that are required in common chemical operations.

The uses of lutes and cements are either to close the joinings of chemical vessels to prevent the escape of vapours and gasses during the processes of distillation, sublimation, and the like, or to protect vessels from the action of the fire which might crack, or fuse, or calcine them: or sometimes to repair flaws and cracks, and for a variety of other smaller purposes.

The subject of *calcareous cements*, such as mortar, tarras, and other substances used to close the joinings of bricks or stones in buildings, will be mentioned in the following article.

When a lute is applied over the whole surface of a vessel, (as to a glass retort when it is intended to be heated red hot) the process is termed, *lutation* or *coating*. Iron furnaces are also *lined* or *coated* on the inside with earth, to prevent the iron from being destroyed by the constant action of the fire.

From the vast variety of receipts for lutes and cements of different kinds, the following may be selected, which will answer most of the purposes of the experimental chemist.

To prevent the escape of the vapours of water, spirit, and liquors not corrosive, the simple application of slips of moistened bladder will answer very well for glass, and paper with good paste for metal. Bladder, to be very adhesive, should be soaked some time in water moderately warm, till it feels clammy; it then sticks very well. If smeared with white of egg, instead of water, it adheres still closer.

Another very convenient lute is linseed meal, moistened with water, to a proper consistence, well beaten, and applied pretty thick over the joinings of the vessels. This immediately renders them tight, and the lute in some hours

dries to a hard mass. Almond paste will answer the same purpose.

The use of the above lute is so extensive, that no other is required in closing glass vessels in preparing all common distilled liquors; and it will even keep in ammonia, and acid gasses, for a longer time than is required for most experimental purposes. It begins to scorch and spoil at a heat much above boiling, and therefore will not do as a fire lute. It is still firmer, and dries sooner when made up with milk, or lime water, or weak glue.

A number of very cohesive cements impervious to water and most liquids and vapours, and extremely hard when once solidified, are made by the union of quick-lime with many of the vegetable or animal mucilaginous liquors. The variety of these is endless. We may first mention the following, as it has been extensively employed by chemists for centuries. Take some whites of eggs with as much water, beat them well together, and sprinkle in sufficient slaked lime, to make up the whole to the consistence of thin paste. The lime should be slaked by being once dipped in water and then suffered to fall into powder, which it will do speedily with great emission of heat, if well burnt. This cement should be spread on slips of cloth, and applied immediately, as it hardens or sets very speedily. While hardening it may be of use to sprinkle over it some of the lime in fine powder. This cement is often more simply and as conveniently managed, by smearing slips of linen on both sides with white of egg, and when applied to the joining of the vessels shaking some powdered lime over it. It then dries very speedily.

Another lute of the same kind, and equally good, is made by using a strong solution of glue to the lime instead of the white of egg. It sets equally soon, and becomes very hard. A mixture of liquid glue, white of egg, and lime, makes

the *lut d'ane*, which is so firm, that broken vessels united with it, are almost as strong as when sound. None of these lutes, however, will enable these vessels to hold liquids for any great length of time. Milk or starch, with lime, make a good, but less firm lute.

A very firm and singular lute of this kind is made by rubbing down some of the poorest skimmed milk cheese with water, to the consistence of thick soup, and then adding lime, and applying as above. It answers extremely well. Lime and blood, with a small quantity of brick-dust, or broken pottery, stirred in, is used in some places as a very good water-cement for cellars and places liable to damp.

Paris-plaster, mixed with egg, milk, glu-, starch, or any mucilaginous liquor, also makes a good lute.

Some artists mix other earths with the above materials. Thus a very good cement is made with equal parts of clay and lime, about $\frac{1}{4}$ of flour and white of egg; or, as is used by many of the *equa fortis*-makers, a mixture of colcothar lime and white of egg.

All the above-mentioned cements, with lime, become very hard, by drying, inasmuch that they cannot be separated from glass vessels without the help of a sharp knife and some violence; and hence delicate vessels, and long thin tubes cemented with it, are apt to break, when the apparatus is taken down, and sometimes even by the mere force of contraction in setting. It is a great advantage, however, that they may be applied immediately to any accidental crack or failure of the lute already on, notwithstanding a stream of vapour is bursting through; and in large distillations it is of advantage always to have some of the materials at hand.

These lutes will not confine very corrosive acid vapours perfectly, for a great length of time, but will answer for other purposes, particularly where a complicated apparatus is to be kept steadily united and air tight. They will bear nearly a red heat without material alteration.

Another kind of lute, which is the most perfect for confining acid vapours for any length of time, and which never hardens to an inconvenient degree, is the *fat lute*, as it is called. This is made by taking any quantity of good clay, tobacco-pipe clay, for example, thoroughly dry, but not burnt, powdering it in an iron mortar, mixing it gradually with drying linseed oil, and beating them together for a long time to the consistence of thick paste. Much manual labour is required, and it should be continued till the mass no longer adheres to the pestle. Then make the edges of the glass or other vessel, where it is to be used, perfectly dry, and apply the lute carefully, and it will stand the longest process without failing. This grows firm enough to retain its place, and to hold the vessels together, but may readily be separated by a knife. This lute much improves in adhesiveness by long keeping, which should be in a covered pan in a cool cellar. When wanted, it regains sufficient ductility, merely by beating for a minute or two, or by the help of a few drops more of the oil. Good glaziers putty, which is made of chalk, beat up with drying linseed oil, much resembles the fat lute in quality.

Another species of lute is that which is commonly applied round glass retorts, when distillation with a full red heat is wanted, to protect them from the sudden action of the fire, and to give them firmness, and to enable them to bear this heat without flattening or falling together, when red hot, or melting with the fuel. A glass vessel, so prepared, with a thick earthen coating, may be considered as an earthen vessel glazed on the inside. The substance used is a mixture of sand, with just sufficient clay to make it adhere together, beat up with some kind of fibrous matter, so as mecha-

nically to increase the tenacity. A natural earthy mixture of the kind is Windsor loam, or an equally good one may be formed with coarse sand and clay, or better with fragments of pottery coarsely ground, (the fine part being separated by sifting, and rejected,) mixed with more or less clay, according to the quality, so that it will just mould together when wet. For the fibrous matter, some use horse-dung, which appears to be the best, others chopped straw or chaff, others chopped horse, or cow-hair, or tow, all of which answer the same purpose. A small quantity of these will suffice. Beaumé recommends about an ounce of cow's hair to five pounds of the earthy mixture. A good deal of water should be added, when the materials are mixed, and much manual labour is required to diffuse the hair equally through the mixture. To apply it to a glass vessel, a retort, for example, take a sufficient quantity of the lute, spread it out flat on a table, lay the bottom of the retort on the middle of the mass, and then turn up the edges of the flat cake, and bring it over the rest of the glass, pressing it down with the fingers, till it applies uniformly and closely. By this method the lute is without seam, and is much more likely to dry in the fire without cracking. Or else, bring the lute, with sufficient water, to the consistence of thick soup, dip the retort in, and it will come out thinly coated. Turn it round before the fire, and, when dry, dip it again in the lute, to give a second coating, and so on, to the required thickness, which may be from $\frac{1}{4}$ to $\frac{1}{2}$ an inch. A lute similar to this is used as a lining to iron furnaces, to confine the fire, and prevent the iron from consuming by the constant heat. This lute is just so fusible as to begin to agglutinate in a full red heat; and hence, if it remains found till thus hot, it will form an impenetrable coating to the glass within, from which it cannot afterwards be detached. The covers of crucibles and other vessels intended to bear fire may be luted with this earthy mixture. It is rendered still less liable to crack on the first heating, if, when thoroughly dry, it is smeared with linseed oil.

Sometimes, however, a still more fusible compound is wanted, particularly where very volatile and penetrating substances are distilled from an earthen vessel. These vessels are necessarily porous, to a certain degree, independent of any casual cracks, from which the larger earthen vessels are seldom entirely free. When phosphorus, for example, is prepared, by strongly heating charcoal and phosphoric acid in one of these retorts, the vapour of the phosphorus penetrates through the pores, when thoroughly red hot, and much of it is lost. Nor will the last-mentioned luting entirely prevent this, so that it is a great saving to cover the retort first with a thin coat of a fusible glazing, which will melt on the surface as soon as red-hot, and close every opening. This glazing may be made by a variety of fluxes added to the proper dose of clay and earth, and mixed into a thin paste and applied to the retort with a brush. The following management is recommended by Mr. Willis, a practical chemist, (*Repertory*, vol. i.) in distillation with large earthen retorts: 1) Solve one ounce of borax in half a pint of boiling water, and add as much slaked lime as will make it into a thin paste. Spread it over the retort with a brush, and, when dry, apply over the whole a lute of slaked lime and linseed oil, beaten till it is perfectly plastic. This becomes dry in a day or two, and is then fit for use. Stone retorts may thus be used several times with safety, (always renewing the oil and lime-lute); whereas, in the common way, and even with the clay and hair-lute, they generally crack when cooling, or on being heated a second time. If, during the operation, the retort should crack, Mr. Willis advises to spread some of the oil composition thickly on the

CEMENTS AND LUTES

part, and sprinkle some slaked lime over the whole, which will prevent the further escape even of the penetrating vapour of phosphorus, and may be safely applied even when the retort is red-hot. When prepared somewhat thicker, it is very proper as a general lute for a variety of purposes, and will never harden so as to break the vessel.

Often a fire lute is required to join the covers to crucibles, or for similar purposes, so as to keep them air-tight when hot. A very valuable composition of the kind is made of glass of borax, brick-dust and clay finely powdered together, and mixed with a little water when used. No very great nicety is required in the proportions, but about a tenth of borax is quite sufficient to bring the earths to that state of semi-vitrification which is desired. Litharge may also be used instead of borax, but the latter is by far the best, as it promotes that thin spreading fusion which is best calculated to be equally applied over an uneven surface; and besides, if a portion of the litharge lute were to drop into the crucible it might possibly be reduced, and lead introduced into the results of the experiments.

A cement, said to be useful to stop cracks of iron vessels intended to be strongly heated, is made of six parts of clay, one of iron filings, and linseed oil enough for the mixture.

Another species of cement is what is termed by the French *Mastic chaud*, and consists of different kinds of oily and resinous substances, liquid when hot, and which become more or less solid by cooling. They are useful for a variety of miscellaneous purposes, for experiments with gasses over water or mercury, and others where only a very moderate warmth is used, and where it is of importance to keep out air and water. These will also confine acid vapours, but not the vapours of alcohol, turpentine, or essential oils, which dissolve most resinous substances. Most of them will stick very well to glass. Common sealing-wax is one of the most useful of these cements. A cheaper and less brittle cement is made simply by melting bees wax with about one eighth of common turpentine. This may be made up into sticks to be used when wanted, being first melted or spread evenly with a hot iron. A greater proportion of turpentine renders this lute softer and more fusible, but somewhat pliable.

A very firm cement is made by four parts of rosin, one of bees wax, and when melted, one part of fine brick dust, stirred in. This adheres with extreme firmness. Table knives are cemented to their handles by this mixture, and turners use a similar composition in some fine works to fix them to the lathe.

Chaptal found, after many trials, that the penetrating vapours of sulphureous acid in the manufacture of alum were completely confined in a wooden chamber lined very carefully with a mixture of equal parts of pitch, turpentine, and wax boiled till all the essential oil was dissipated (which was known by the cessation of the bubbles) applied melted to the wood, and spread with a hot trowel over the joints. Vintners stop leaks in their casks with melted suet rubbed over when cooling with sifted wood-ashes, or previously mixed with the ashes in melting.

The use of gum arabic dissolved in water, for cementing paper labels to bottles, and a great variety of miscellaneous purposes, is known to every one. A still better cement for the same use is isinglass dissolved in vinegar to a pretty thick consistence when warm. This congeals on cooling, and before it is used it should be gently warmed.

Many of the varnishes and oil paints are employed in rendering vessels air and water tight. Thus when canvas bags are fastened to a stop-cock tube for air-holders, the joining

is made perfectly tight by tying over it slips of cloth or bladder soaked in spirit varnish.

The following cement is said to be very useful in joining together glass or steel. Take of mastic five or six bits as big as peas, dissolve in as much alcohol as will render them liquid. In another vessel dissolve as much isinglass (previously soaked in water) in brandy or rum, as will make two ounces by measure of a strong gluc, warm it, and incorporate with it by rubbing two or three small bits of galbanum or ammoniacum and then the mastic solution. Keep the cement in a bottle well stopped, and gently warm it before use.

Those fusible metal compounds used to unite pieces of metal form another totally distinct species of cements. These are termed **SOLDERS**, under which they will be described. See **CEMENT**.

CEMENTS, calcareous. In this article it is proposed to give an account of the various cements used in building, into which lime enters as an essential constituent part; and in order to treat the subject with a degree of clearness, in some measure corresponding to its importance, it will be advisable to arrange every kind of calcareous cement under one or other of the following three divisions: first, simple calcareous cements; secondly, water cements; thirdly, mastics or maltha.

§ 1. Simple calcareous cements.

This section includes those kinds of mortar which are employed in buildings on land; and generally consist of lime, sand, and fresh water.

It is well known that calcareous earths are converted, by burning, into what is called quick lime, which substance being wetted with water falls into a powder with great extrication of heat, and then acquires the property of uniting with sand, and various other substances, and forming a solid mass which becomes as hard and durable as most building stones. We have no means of ascertaining by whom or at what time this valuable property of lime was discovered; but among the nations of antiquity the Romans appear to have made the most use of, and to have been most skilled in cementitious building.

The various kinds of marble, chalk, and lime-stone, as far as regards their use in cements, may be divided into two species; the first being pure or nearly pure carbonate of lime; the second containing besides from $\frac{1}{10}$ to $\frac{1}{7}$ of clay and oxyd of iron. Previous to burning or calcination, there are no external characters by which the simple lime-stones can be distinguished from the argillo-ferruginous ones; but the former, whatever may have been their colour in a crude state, become when calcined of a white colour, while the latter possess more or less of a light ochery tinge. The brown lime is by far the best for all kinds of cements; but the white varieties being more abundant, and allowing of a larger proportion of sand, are generally made use of. It was an opinion of the ancients, and is still commonly received among builders, that the hardest lime-stone, *ceteris paribus*, furnishes the best lime; thus mortar was said to grow as hard as the lime-stone of which it was composed, and hence marble was considered as superior to common lime stone, and this latter to chalk. The experiments of Dr. Higgins and Mr. Smeaton, however, show that this is entirely a mistake; common chalk, and the hardest Plymouth marble, when similarly treated, affording cements of equal firmness.

When carbonated lime has been thoroughly burnt, it is deprived of its water, and of all, or nearly all of its carbonic acid: if, in this state, it is plunged into water, and immediately taken out again, the water which it has absorbed

will occasion the mass to crack and become excessively hot, and at length to fall into an impalpable powder, much of the water being carried off in the form of steam during the process. When lime has been thus slaked, if it is beaten up with a little water into a very stiff paste and allowed to dry, it will be found that the white limes, whether from chalk or marble, never acquire any degree of hardness, that the brown limes become considerably indurated though not so much so as when mixed with sand, and that shell lime (procured by calcining sea shells), concretes into a firm, hard cement, well qualified for dry buildings, although it falls to pieces in water.

Lime-stone loses about $\frac{1}{3}$ of its weight by burning, but shrinks in an inconsiderable degree; upon quenching, when fully burnt, it falls freely, and will produce somewhat more than double the quantity of powder or slaked lime, in measure, that the burnt lime-stone consisted of.

Quick-lime, by exposure to the air, absorbs carbonic acid with greater or less rapidity, as it is of a close and hard, or soft and spongy texture; thus it gradually loses its cementing properties and at length becomes totally unfit for the purposes of mortar. Hence, though stone-lime and chalk-lime are equally good, when perfectly burnt, and used fresh from the kiln, there is an important practical difference between them, as the chalk-lime absorbs carbonic acid with much the greatest facility.

A proper selection of sand is of great importance in the composition of mortar; the sharper and coarser it is the better; as it requires a smaller proportion of lime, and makes a stronger cement than when fine grained and round sand is made use of. Sea sand requires to be well washed in fresh water to dissolve out the salt with which it is mixed, otherwise the cement into which it enters never becomes thoroughly dry and hard.

The most advantageous proportions of lime and sand in the composition of mortar is a point by no means settled. The Roman builders were accustomed to allow three parts of pit sand, or two parts of river or sea sand to one of lime. In general, it may be affirmed, that it will be advantageous to use the largest quantity of sand that can be introduced, preserving the necessary degree of plasticity. Mortar, in which the sand predominates, requires less water in preparing, and therefore sets sooner; it is harder and also less liable to crack on drying than that in which lime prevails. Smeaton observes, that there is scarcely any but what, if well burnt and beaten, a load or measure of unslaked lime will take two loads or measures of sand. On pursuing this subject he soon found that, by good beating, the same quantity of lime would take in one measure of tarras and three of clean sand, which seems to be the greatest useful proportion, for on a further increase of the quantity of sand, the mortar required so much more beating to bring it to a proper consistence and toughness, that the labour became of more value than the saving of materials. These observations agree very nearly with the experiments of Dr. Hutton.

The weakness of modern mortar compared to the ancient is a common subject of regret, and many ingenious men taking for granted, that the process used by the Roman architects in preparing their mortar is one of those arts which are now lost, have employed themselves in making experiments to recover it, instead of attending to the directions left us in the works of Pliny and Vitruvius, which, when illustrated by the actual practice of builders in various parts of Europe, seem to leave little or no doubt on the subject.

The characteristic of all modern artists, builders among the rest, seems to be to spare their time and labour as much as possible, and to increase the quantity of the articles they

produce, without much regard to their goodness; and perhaps there is no manufacture in which this is so remarkably exemplified as in the preparation of common mortar, especially in London and its neighbourhood.

The peculiar badness of London mortar is to be attributed, both to the faulty nature of the materials, and the careless and hasty method of using them. The lime employed is the soft chalk-lime of Essex and Kent, which insufficiently burnt at first, is conveyed a distance of ten or twenty miles and kept many days, without any precautions to prevent the access of the external air; and thus before it is used, it has time to absorb so much carbonic acid as nearly to lose its cementing properties. It has been before observed, that though chalk, when perfectly burnt, is equally good as the hardest lime, it possesses some practical disadvantages; it will fall into a coarse powder on the application of water, when it is only partially calcined, which stone-lime will not, and the cores or unburnt lumps may be broken down by a blow with the spade, and are therefore very seldom rejected as they ought to be.

Sand, which is scarce and dear in London, is equally defective. This is pit sand, but very different from the kind recommended by Pliny and Vitruvius; instead of being clean, large-grained, and sharp, it is composed of small round grains, and soiled with a large mixture of clay. Its fineness and smoothness cannot be amended, but by washing it well in running water the clay might unquestionably be got rid of, and this would be no trifling improvement, for Smeaton has shown, by direct experiment, that mortar of the best quality, when mixed with a small proportion of unburnt clay, never acquires that hardness and dryness which, without this addition, it would speedily have attained. Screened rubbish and the scrapings of the roads, consisting chiefly of gravel reduced to fine powder, are also used as substitutes for sand with still greater impropriety.

The method of preparing common mortar is also extremely imperfect. The lime being slaked by the addition of water, and the unburnt lime being broken down and mixed with the rest, a quantity of dirty sand is added, and the whole being incorporated by means of a spade, is reckoned to be fit for use; thus the principal point in the making of mortar, namely, beating the ingredients together, so as to mix them thoroughly, is slurred over in a hasty careless manner, and the result, as might be expected, is a crumbling mass scarcely fit for use. The Roman builders, on the other hand, after they had mixed together the materials, employing for this purpose a smaller proportion of water than is customary at present, put the mass into a large wooden mortar, and beat it till it ceased to adhere to the heavy wooden or iron pestle which was used on the occasion; a practice, which has long been followed by the Dutch with complete success, as will be shewn in the next section.

Fresh made mortar, if kept under ground in considerable masses, may be preserved for a great length of time without injury; and the older it is before it is used the better; the builder taking the precaution to beat it up afresh, previous to using it; for it not only sets sooner, but acquires a greater degree of hardness, and is less apt to crack. A fact related by Mr. Smeaton, remarkably illustrates these points. Having had occasion to take up a large flat stone of a close grain, of about five feet square, that had probably lain above a century at the bottom of a malt cistern, he found that it had been well bedded in mortar, which had become coagulated to the consistence of cheese; but having never come to a perfect dryness, it so far retained its natural humidity, that he found it might, with some pains, be beaten up to mortar

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without any addition of water; and afterwards being suffered to dry in the air, it set to a stony hardness, and appeared as good mortar as any which that part of the country produced. Pliny informs us, that the ancient Roman laws prohibited builders from using mortar that was less than three years old; and to this circumstance he expressly attributes the remarkable firmness of the oldest buildings in the city. A similar custom prevailed, and we believe still prevails in Vienna, requiring the mortar to be a year old before it is employed. But there is nothing which shows, in so striking a point of view, the advantage and necessity of beating mortar, and that the effect produced is owing to something more than a mere mechanical mixture of the ingredients, as the preparation of *grout*, or liquid mortar. This differs from common mortar only in containing a larger quantity of water, so as to be sufficiently fluid to penetrate the narrow irregular interstices of rough stone walls, and is generally made by diluting common mortar with water, either cold or hot. It not unfrequently happens, that this grout refuses to set, and at all times it is a long while in acquiring the proper hardness; but if, instead of common mortar, that which has been long and thoroughly beaten is employed, the grout will set in the space of a day, and soon after acquires a degree of hardness much superior to what is made in the common manner.

§ 2. *Water Cements.*

Although a well made mortar, composed merely of sand and lime, if allowed to dry, becomes impervious to water, so as to serve for the lining of reservoirs and aqueducts; yet if the circumstances of the building are such as to render it impracticable to keep out the water, whether fresh or salt, a sufficient length of time, the use of common mortar must be abandoned; for lime and sand, if mixed together in any proportions, and put, while soft, into water, will in a short time fall to pieces.

Among the nations of antiquity the Romans appear to have been the only people who practised building in water, and especially in the sea, to any great extent. The bay of Baiz, like our fashionable watering places, was the summer resort of all the wealthy in Rome; who, not content with erecting their villas as near the shore as possible, were accustomed to construct moles, and form small islands, in the more sheltered parts of the bay, on which, for the sake of the grateful coolness, they built their summer houses and pavilions. They were enabled to build thus securely in the water by the fortunate discovery, at the neighbouring town of Puteoli, of an earthy substance, which, from this circumstance, was called *pulvis Puteolanus* (powder of Puteoli.) Puteolan powder, or as it is now denominated puzzolana, is a light, porous, friable mineral, of a red colour, and is generally supposed to derive its origin from concentered volcanic ashes, thrown out from Vesuvius, near to which mountain the town of Puteoli is situated. It seems to consist of a ferruginous clay, baked and calcined by the force of volcanic fire, and when mixed with common mortar, not only enables it to acquire a remarkable hardness in the air, but to become as firm as stone, even under water. The only preparation which puzzolana undergoes, is that of pounding and sifting, by which it is reduced to a coarse powder; in this state being thoroughly beaten up with lime, either with or without sand, it forms a mass of remarkable tenacity, which speedily sets under water, and becomes at least as strong as good freestone.

It has been before observed, that a composition of pure lime and sand alone will not harden under water, but limes containing a portion of clay possess this property in a considerable degree, and are therefore generally used in water

building. The cement used by Mr. Smeaton, in the construction of the Eddystone lighthouse, was composed of equal parts by measure of slaked Aberthaw lime and puzzolana. The peculiar difficulties of this undertaking, exposed to the utmost violence of the sea, rendered these proportions advisable; but for works that are less exposed, such as locks and basins for canals, &c. the quantity of puzzolana may be considerably diminished. A composition of this kind, which has been found very effectual, is 2 bushels of slaked Aberthaw lime, 1 bushel of puzzolana, and 3 of clean sand; the whole being well beaten together will yield 4.67 cubic feet of cement.

The Dutch have practised building in water to a greater extent than any other nation of modern Europe; and to them is due the discovery of a cement admirably well adapted for this purpose, and called *tarras* or *trals*. This is nothing more than wakke, or cellular basalt, and is procured chiefly from Bockenheim, Frankfort on the Maine, and Andernach, whence it is transported down the Rhine in large quantities to Holland. This substance being, by grinding and sifting, reduced to the consistence of coarse sand, is used in the composition of mortar, with the blue argillaceous lime from the banks of the Scheldt, in the following method. They take of the quick-lime about the quantity which will be wanted during a week, and spread it in a kind of basin in a stratum of a foot thick, and sprinkle it with water. It is then covered with a stratum of about the same thickness of *tarras*, and the whole suffered to remain for two or three days, after which it is very well mixed and beaten, and formed into a mass, which is again left for about two days; it is then taken in small quantities, as it is wanted for daily consumption, which are again beaten previous to using. Thus is composed the celebrated *tarras* mortar with which the mounds and other constructions for the purpose of protecting the lowlands of Holland against the sea are cemented.

Tarras is frequently used in this country, being imported from Holland for that purpose. The proportions of the materials of the *tarras* mortar generally used in the construction of the best water works is the same as the Dutch practice. One measure of quick-lime, or two measures of slaked lime in the dry powder, is mixed with one measure of *tarras*, and both very well beat together, to the consistence of a paste, using as little water as possible. Another kind, almost equally good, and considerably cheaper, is made of two measures of slaked lime, one of *tarras*, and three of coarse sand; it requires to be beaten a longer time than the foregoing, and produces three measures and a half of excellent mortar. When the building is constructed of rough irregular stones, where cavities and large joints are to be filled up with cement, the pebble mortar may be most advantageously applied; this was a favourite mode of construction among the Romans, and has been used ever since their time in those works in which a large quantity of mortar is required. Pebble mortar will be found of sufficient compactness if composed of two measures of slaked argillaceous lime, half a measure of *tarras*, or puzzolana, one measure of coarse sand, one of fine sand, and four of small pebbles, screened and washed.

It is only under water that *tarras* mortar acquires its proper hardness; for if suffered to dry by exposure to the air, it never sets into a substance so firm as if the same lime had been mixed with good clean common sand, but is very friable and crumbly. Ash mortar is reckoned to be superior for works that are sometimes wet and sometimes dry, but *tarras* has the advantage when constantly under water. *Tarras* mortar when kept always wet, and consequently in a state most favourable to its cementing principle, throws out a

substance something like the concretions in limestone caverns called stalactites, which substance acquires a considerable hardness, and in time becomes so exuberant as to deform the face of the walls.

Although the cellular basalt is the only kind admitted into the preparation of Dutch tarras, yet it appears from some good experiments of Morveau on the subject, that the common compact basalt, if previously calcined, will answer nearly the same purpose. Great Britain is at a considerable annual expence in purchasing tarras from Holland; it may be worth while, therefore, to point out some of our domestic treasures of the same material. The compact basalt abounds in all the districts where coal is raised, and may therefore be procured easily, and calcined with the refuse coal, so as to be sold at a cheap rate. The Calton hill, adjoining to Edinburgh, consists almost entirely of cellular basalt, and being but at a short distance from the port of Leith, offers an inexhaustible abundance at a small cost.

In some parts of the Low Countries coal ashes are substituted for tarras with very good effect; of which the valuable *ceadrée de Tournay* is a striking instance. The deep blue argillo-ferruginous limestone of the Scheldt is burnt in kilns with a slaty kind of pit-coal that is found in the neighbourhood. When the calcination of the lime is completed, the pieces are taken out, and a considerable quantity of dust and small fragments remains at the bottom of the kiln. This refuse consisting of coal ash mixed with about one-fourth of lime dust, is called the *ceadrée*, and is made into a mortar with lime in the following method. About a bushel of the materials is put in any suitable vessel, and sprinkled with water just sufficient to slake the lime; another bushel is then treated in the same way, and so on till the vessel is filled. In this state it remains some weeks, and may be kept for a much longer time if covered with moist earth. A strong open trough, containing about two cubic feet, is filled about two-thirds full with the cement in the above state, and by means of a heavy iron pebble, suspended at the end of an elastic pole, is well beaten for about half an hour: at the end of this time it becomes of the consistence of soft mortar, and is then laid in the shade from three to six days, according to the dryness of the air. When sufficiently dry, it is beaten again for half an hour as before, and the oftener it is beaten the better will be the cement; three or four times, however, are sufficient to reduce the cement to the consistence of an uniform smooth paste; after this period it is apt to become refractory on account of the evaporation of its water, as no more of this fluid is allowed to enter the composition than what was at first employed to slake the lime. The cement thus prepared is found to possess the singular advantage of uniting in a few minutes so firmly to brick or stone, that still water may be immediately let in upon the work without any inconvenience, and by keeping it dry for 24 hours, it has nothing further to fear from the most rapid current.

A composition very similar to the preceding in materials, which are coal cinders and lime, though seldom prepared with any attention, is the blue mortar, commonly used in London for setting the coping of buildings, and other works much exposed to the weather.

Ash mortar is used in some parts of England. It is prepared by slaking two bushels of fresh burnt meagre lime, and mixing it accurately with three bushels of wood ashes: the mass is to lie till it is cold, and is then to be well beaten: in this state it will keep a considerable time without injury, and even with advantage, provided it is thoroughly beaten twice or thrice before it is used.

The scales of black oxyd, which are detached by hammering red-hot iron, and are therefore to be procured at the

forges and blacksmiths shops, have been long known as an excellent material in water cements; but we believe that Mr. Smeaton was the first person who made any accurate experiments on their efficacy, compared with other substances. The scales being pulverised and sifted, and incorporated with lime, are found to produce a cement equally powerful with puzzolana mortar, if employed in the same quantity. Induced by the success of these experiments, Mr. Smeaton substituted roasted iron ore for the scales, and found that this also gave to mortar the property of setting under water; it requires, however, to be used in greater proportions than either tarras or puzzolana; two bushels of argillaceous lime, two of iron ore, and one of sand, being carefully mixed, produce 3.22 cubic feet of cement fully equal to tarras mortar. If the common white lime is made use of, it will be advisable to employ equal quantities of all the three ingredients.

With respect to the water used in the preparation of water cements, that of rivers or ponds where it can be had easily, is to be preferred to spring water; but for works exposed to the action of the sea, such as piers, light-houses, &c. it is usually more convenient and equally advantageous in other respects to use salt water.

Pumice stone, brick, and tile dust, are also recommended for water cements, but their only advantage seems to be an absorbent quality, which causes the mortar made with them to set sooner, and therefore acquire a greater hardness in the same time, than mortar composed of sand and lime alone, for they have no power of hardening under water.

The Lorient mortar is a composition which has acquired considerable celebrity in France, and has been employed in some large works. It was invented about 40 years ago by Mr. Lorient, who imagines that he has discovered the process used by the Romans. The principle of this invention consists in adding to any quantity of mortar made in the usual way with lime and sand, but prepared rather thinner than usual, a certain proportion of quick lime, in powder. The lime powder being well incorporated with the mortar, the mass heats, and in a few minutes acquires a consistence, equal to the best Paris plaster, and is as dry at the end of two days, as an ordinary cement after several months. It also, when the ingredients are well proportioned, sets without any cracks. The quantity of lime powder to be added, varies from $\frac{1}{4}$ to $\frac{1}{2}$ of the other materials, according to the qualities of the lime; too much burns and dries up the mass, and with too little, it loses its peculiar advantages; thus the proportions, a point of the utmost importance, can only be determined by experiment. It is its speedy desiccation which rendered the Lorient mortar useful as a water cement, for under water it has only the common properties of a composition of lime and sand of equal solidity; indeed for this purpose various substances, commonly used in cements, are recommended to be added, such as brick and tile powder, and forge scales. The following is an approved receipt. One measure of bricks exactly pounded, two measures of fine river sand, old slaked lime in sufficient quantity to make a mortar in the usual manner and sufficiently liquid to quench the lime powder which is added in about the same quantity as the pulverised brick.

It is sufficiently extraordinary, that a process, perfectly similar to that of M. Lorient, is described in a "Treatise on Building in Water, by George Semple," printed at Dublin, 1776. In discoursing on the good qualities of the roach-lime of Ireland, Mr. Semple remarks, that, "it has some useful qualities not much known among the generality of workmen, as, for instance, our lime-stone will make exceeding good tarras for water-works, for which purpose, you are

to prepare it thus. Get your roach-lime brought to you hot from the kiln, and immediately pound, or rather grind it, with a wooden maul, on a dry, boarded floor, till you make it as fine as flour; then, without loss of time, sift it through a coarse hair or wire sieve, and, to the quantity of a hod of your setting mortar, (which, on this account, ought to be poorer than ordinary,) put in two or three shovels-full of this fine flour of the roach-lime, and let two men, for expedition sake, beat them together with such beaters as the plasterer make use of, and then use it immediately. This, I can assure you, will not only stand as well, but is really preferable to any tarras." The memoir of M. Lorient was published in 1774, only two years previous to this treatise of Semple, who appears to have been a man rather of practice and experience than of reading; and, besides, in the book quoted from, he expressly, though incidentally, mentions his ignorance of the French language. We are justified therefore, in stating, that the knowledge of the advantages of mixing quick lime powder in mortar was not confined to M. Lorient, though it might be an original invention in him, and he was the first who drew public attention to the process, and used it in any considerable works.

§ 3. *Maltha, or Mastich.*

Under this term we include those calcareous cements of a more complicated kind, whose hardness appears to depend on the oily or mucilaginous substances that enter into their composition. The use of these is at present very limited, at least in Europe, but they were highly esteemed by the ancients, especially for stucco. The maltha of the Greeks seems to have been more simple than that employed by the Roman architects; at least we are informed that Panænius, the brother of Phidias, lined the inside of the temple of Minerva at Elis with a stucco, in which the usual ingredients, sand and lime, were mixed up with milk instead of water, some saffron being also added to give it a yellow tinge. The Roman maltha, according to Pliny, was prepared in the following manner. Take fresh burnt lime, flake it with wine, and beat it up very well in a mortar with hog's lard and figs: this cement, if well made, is excessively tenacious, and, in a short time, becomes harder than stone; the surface to which it is to be applied is to be previously oiled, in order to make it adhere. Another kind, almost equally strong, and considerably cheaper, was prepared by beating up together fine slaked lime, pulverized iron-scales and bullock's blood.

In the preparation of mastichs, as well as of every other kind of mortar, so much depends on the manipulation, and especially on the care which is taken to incorporate the ingredients by long beating, that those countries

in which labour is of the least value possess, in general, the best mortar. Hence, no doubt, principally arises the unrivalled excellence of the mortar made by the Tunisiens and other inhabitants of the northern coast of Africa, which, according to Dr. Shaw, is prepared in the following manner. One measure of sand, two of wood-ashes, and three of lime, being previously sifted, are mixed together, and sprinkled with a little water; after the mass has been beaten some time a little oil is added: the beating is carried on for three days successively, and, as the evaporation in that hot climate is considerable, the cement is kept at the proper degree of softness by the alternate addition of very small quantities of water and oil. The cement being completed, is applied in the usual manner, and speedily acquires a stony hardness. The last species of maltha that we shall mention is the celebrated chunam of India, where it has been used from time immemorial. The method in which it is prepared at Madras is as follows.

Take 15 bushels of pit sand, and 15 bushels of stone-lime; flake the latter with water; and when it has fallen to powder, mix the two ingredients together, and let them remain untouched for three days. In the mean time dissolve 20lbs. of molasses in water, boil a peck of gramm (a kind of pea), to a jelly, boil a peck of mirabolans also to a jelly, mix the three liquors, and incorporate part of the mixture very accurately with the lime and sand, so as to make a very fluid cement: some short tow is now to be beaten very well into it, and it is then fit for use. The bricks are to be bedded in as thin a layer as possible of this mortar; and, when the workmen leave off, though but for an hour, the part where they recommence working is to be well moistened with some of the above liquor, before the application of any fresh mortar. When this is used for stucco, the white of four or five eggs, four ounces of butter or sesamum oil, and a pint of butter-milk, are to be mixed up with every half bushel of cement, and the composition is to be applied immediately.

It is to be regretted, that no experiments have been instituted to ascertain the cause of the induration of calcareous cements. It is attributed by Dr. Higgins to the absorption of carbonic acid; but several circumstances contradict this supposition. In numerous instances the cement hardens long before the lime is saturated: in the different kinds of maltha the lime combines with the albumen, mucilage and oil with which it is in contact, and in all probability takes up little or no carbonic acid; and, if it be true, that the lime in old mortar cannot by burning be re-converted into quick lime, this would imply a chemical union of the ingredients; and it may reasonably be questioned whether, even in the simple calcareous cements, carbonic acid acts so important a part as is usually attributed to it.

Chaff-Cutter

Chaff-Cutter, in *Rural Economy*, an implement constructed for the purpose of cutting hay, straw, and other substances into chaff. Instruments of this sort consisted formerly simply of a box and a cutting blade; but they are at present much improved, being made of different forms and constructions, so as to perform the work with greater economy and dispatch. Mr. Cook has invented one, which, by means of a man and boy, will cut one hundred quarters a week; and when fixed to a large wheel, and turned by an animal, such as a poney or ass, will cut half the above quantity per day. Another contrived by Mr. Noller is capable of cutting three quarters an hour, by the assistance of two men, and costs about ten guineas. An instrument for this purpose, made by Mr. James Pihe, is likewise both cheap and of the most simple construction. It is fixed on a wooden frame, which is supported with four legs; and on this frame is a box for containing the straw, four feet six inches long, and about ten inches broad: at one end are fixed across the box two rollers, inlaid with iron, in a diagonal line, about an eighth of an inch above the surface; on the ends of these rollers are fixed two strong brass wheels, which take one into the other. On one of these wheels is a contract wheel, whose teeth take in a worm on a large arbour; on the end of the arbour is fixed a wooden wheel, two feet five inches diameter, and three inches thick. On the inner part of this wheel is fixed a knife, and at every revolution of the wheel the knife passes before the end of the box, and cuts the chaff, which is brought forward between the rollers, which are about two inches and a half asunder. The straw is brought on by the worm taking one tooth of the wheel every round of the knife: the straw being so hard pressed between the rollers, the knife cuts off the chaff with so great ease, that twenty-two bushels can be cut within the hour, and makes no more noise than is caused by the knife passing through the chaff. It consists of the box into which the straw is put, and an upper roller, with diagonal projecting ribs of iron; the whole moving by the revolution of the brass wheel, on the axis of which it is fixed. Another brass wheel has upon it a face wheel, whose teeth take into the endless screw on the arbour, while the teeth on the edge of this wheel enter between those on the edge of the other wheel. On the axis of the latter brass wheel is a roller with iron ribs, similar to the above, but hid within the box.

The arbour has one of the ends of which it is composed made square, and passing through a mortise in the center of the wooden wheel, which is fastened by a strong screw and nut; the other end of this arbour moves round in a hole within the wooden block; and the knife is made fast by screws to the wooden wheel, and kept at the distance of nearly three quarters of an inch from it, by means of a strip of wood of that thickness, of the form of the blade, and reaching to within an inch of the edge. The handle is mortised into the outside of the wooden wheel.

An improved machine of this sort has been invented by Mr. Robert Salmon, of Woburn, Bedfordshire, and described in the Transactions of the Society for the Encouragement of Arts, &c. With it the chaff is cut by two knives, fixed on the inside of the felloes to two wheels, which are strongly connected together; the edge of the knives being at an angle of about forty-five degrees from the plane of the wheel's motion. These knives are so fixed as to be forced forward by springs on the wheel, which springs are formed to adjust, and act more or less, as occasion may require, so as to give the knives as much pressure against the box as may be requisite to cut the straw. The knives are prevented from coming too forward, and occasioning unnecessary friction, by wedges being put in under the staples; which wedges, as the knives wear, must be drawn out so as to admit the knives to come more forward. With the before-mentioned provisions, it will be found very easy at any time to put on new knives, as the springs, &c. will always adjust them to their work.

On one side of the wheel is fixed a round block of wood, in which there are four holes and a moveable screw; to this block is screwed one end of the feeding-arm, running nearly horizontally to the cross bar at the end of the box; to which cross bar there is a pin, moveable to five different holes, by means of which, and the four holes in the block before described, twenty changes in the length of the chaff may be obtained. The straw is brought forward by the rollers in the box, the form of which has been just described, which rollers are turned from the outside by the triggers or ratchet-wheels on each side of the box, which move more or less, according to the stroke given to the cross bar by the feeding-arm and wheel. By this mode of feeding, the straw is per-

feebly at rest, and does not press forward at the time of the knife cutting; and, by means of the pins being taken out of the cross-bar, the feeding is instantly thrown off, although the wheel and knives may continue their motion. Under the box is suspended the pressing weight, which may be made more or less powerful by shifting the weight on the bearer to which it hangs, and also may be thrown on either side, more or less, as occasion may require; which will be found useful, in order to force the straw towards the knife, and to counterbalance the ratchet-wheel of the upper roller. Near the fulcrum of this bearer is fixed a chain, the upper end of which is suspended from a roller; at each extremity of which is a small bar of iron, joined to the end of the upper spiked roller, by which means the straw is always equally pressed in passing the two-spiked rollers. The winch by which the machine is turned is of the common kind, and the frame of the machine is to be made very firm and strong.

In order to apply this implement to the best advantage, the inventor proposes a second box, to be placed at the end of the first; which box may be of any length, and suspended by a line and counter-weight, whereby the end of it is brought down level whilst filling with straw, and then drawn up, so as to give the box a declivity, to make the straw more easily come forward.

It is supposed that much advantage may be derived in this instrument from its cutting various lengths, resting during the cut, the knives being adjusted to their work by regulating springs, the feeding being readily thrown off, and the pressure moveable to either side. It is also well calculated to be applied to any power which may be occasionally fixed to the opposite side to that on which it is turned by hand; and, by the additional box, when used by hand, the workman will be enabled to cut for some continuance, without stopping to feed.

Where threshing machines are in use, these implements may frequently be attached to them with great advantage. There are many other instruments of this sort constructed in different ways; but those which are the least complex, and can be afforded at the cheapest rate, are the most adapted to the purpose of the farmer. See CUTTING-BOX.

The above machine, as considerably altered and improved by Mr. Rawntree, is seen in *Plate VII. on Agriculture*, in which *fig. 1.* is a side, and *fig. 2.* an end view of it. The advantages of this implement are, 1st, Its great simplicity; 2d Its cutting the chaff of various lengths; 3d, The straw being at rest while the knives are making the cut; 4th, The friction being less, more work of course may be done with equal labour.

A, is the handle.

B, B, the fly-wheels on which the knives are fixed.

C, the ratchet-wheels, and rollers for drawing the straw forwards.

D, the rods to work the ratchet-wheels, connected with the lever and crank.

E, the box for containing the straw.

F, the lever and weight for pressing the straw.

G, the knives.

H, the crank for regulating the cut.

I, the frame.

At *fig. 3.* is represented Mr. M'Dougall's patent chaff-cutter, which is a very useful instrument of this kind. In this machine the inventor has been particularly careful so to construct it, that, in case it should be accidentally broken, it might be easily repaired by any common mechanic. The substance to be cut into chaff may be pressed as hard as the workman chooses, by simply placing the weight near to the end of the lever. But the chief excellence of the instrument consists in the inventor having judiciously applied a spiral groove in the room of the endless screw, commonly used by other agricultural instrument-makers, by means of which he has in a great degree got rid of friction; and the lever may rise to any height, without putting the machine out of work.

It has been remarked by Mr. Young, that the number of machines which have been invented of late years for this purpose, most of which perform their work with sufficient accuracy, leaves no farmer in the kingdom under the necessity of employing the common chaff-box, which is worked by those only who have acquired the art of making use of it, and who commonly make much greater wages per day than the ordinary pay. He observes that there is a very good machine of this sort made at Thetford, which only costs eight guineas. It has been observed by a late practical writer, that as the principal objects aimed at in the construction of these machines are those of expedition and the lessening of manual labour, it is evident that many of those of the improved kind must answer such purposes much more effectually than such as were formerly in use, especially where they are attached to any great power, such as that of horses, water, &c. as in the case of threshing machines, or other mills, to which they are in general well suited, as has been noticed above.

Mr. Page of Cobham has, according to Mr. Young, at the trifling expence of only five pounds, added a mill-wheel to his chaff-cutter, by which means a boy and a little poney cut twenty bushels of chaff per hour.

Chalk

CHALK. The colour of this mineral is yellowish white, more rarely snow-white, or greyish white : when contaminated with iron it has more or less of an ochery tinge. It occurs generally in mass, sometimes disseminated, or investing other minerals. It is without lustre, is opaque, has a fine earthy fracture, and breaks into blunt-edged angular fragments. It stains the fingers, gives a white streak, and, when pure, is very soft, and almost friable. It has a meagre feel, and adheres to the tongue. Sp. gr. 2.3. It effervesces violently with acids. When mixed with iron it is both harder and heavier.

In a state of purity, chalk appears to be composed only of water, lime, and carbonic acid ; but Mr. Kirwan obtained from the analysis of a specimen,

53	Lime
42	Carbonic acid
3	Water
2	Alumine

100

Chalk, considered geologically, is among the most recent in formation of the several varieties of carbonate of lime. It occurs in thick beds nearly horizontal, alternating with thin layers of flint nodules, and with the same irregularly dispersed through its substance. It contains in abundance the relics of marine organized bodies, such as echinites, glossopetræ, peccinites, &c. ; and also, not unfrequently, the hard parts of amphibious and land animals, such as the heads and vertebrae of crocodiles, and teeth of elephants.

Beds of chalk are of frequent occurrence in the east and south parts of England, also in the north east of France. Chalk is also met with in some of the Danish islands in the Baltic, and in Poland.

The uses of chalk are very great. The more compact varieties are employed as building-stone, and are burnt to

quicklime : it is also largely used in polishing metals and glass, in constructing moulds to cast metals in ; by carpenters and others as a material to work with, and by starch-makers and chemists to dry precipitates on.

CHALK, in Agriculture, is a calcareous substance, which, when pure, is of a white colour, moderate consistence, and dusty surface ; stains the fingers ; adheres slightly to the tongue ; does not harden when heated, but, on the contrary, in a strong heat burns to lime, and loses about four-tenths of its weight. It effervesces with acids, and dissolves almost entirely in them. It may also be added, that this solution is not disturbed by caustic volatile alkali, as this is a circumstance that distinguishes it from magnesia. It has the property of promoting putrefaction. In its native state it is useful as a manure, upon the same principle as limestone ; but it is more easily pulverized, and lighter, or more porous in its nature. Nearly the whole of this material is calcareous earth, whereas none of the marls contain more than a fourth part of that substance. It is in high esteem in the more southern counties of England, where it abounds very much. Its best effects are produced upon deep soils which contain no calcareous earth. It is observed to have but very little effect upon lands where the substratum is chalk ; and if the soil be thin, it does mischief in such cases. When used upon light thin soils, it is mostly made into composts with earth and dung, or some other similar material. When these are well mixed together, and duly proportioned, they produce valuable crops ; and their influence is said to continue many years, in such instances.

The common method of using this sort of compost is either by laying it upon fallows for wheat, and mixing it intimately with the soil by ploughing and harrowing, or upon grass as a top-dressing : in both cases it has been found to answer well ; and in the latter it is found capable of destroying moss, rushes, and all coarse aquatic plants that grow

in heavy, sour, or wet lands; while, in the former, it opens and pulverizes the soil, and never fails to produce good crops of that grain, or other kinds.

In making use of it, it has been recommended that it should be broken as small as possible. It should be dug from the pit near the end of autumn, and be laid on the land immediately; as at that season the air is generally moist, the moisture will of course be absorbed by the chalk. This will occasion it to swell, and break down into pieces; and if frost should come on, it will much accelerate the business; but when it is dug in summer, it loses its moisture, and acquires a hardness, which in a great measure prevents it from being of any use. It should in no case be ploughed in till its parts are properly broken down and separated, and then it should be completely harrowed in and mixed well with the soil, or mould of the land.

If the soil be thin and light, a certain proportion of dung will, it is said, be useful; but if it be heavy, the dung is asserted to lessen the operation of the chalk. It is generally thought that lands which have been completely chalked will not bear a repetition of it for some time. A compost of it, however, may be used to great advantage. In the southern counties a field has been, it is observed, chalked, and dressed with chalk and dung mixed, in portions alternately; and the former has been found to produce very bad crops, but the latter very good ones. It is asserted, that laid on beyond a certain quantity, it will not only cease to operate as a manure, but even prove hurtful to the land. It ought, therefore, to be used with caution, and due pains be taken not only to ascertain the strength of the chalk, but the quality of the soil on which it is to be laid, before the application is made.

But there can be no doubt that chalk is a lasting manure, when applied on suitable soils; which are those of a cold, sour nature, such as stiff untractable clays. Pliny has remarked that it was the custom of the ancient Britons to chalk their lands, by which they received a great and lasting improvement in the fertility of them.

In regard to the different kinds of chalk which should be distinguished by the farmer, the hard, dry, and firm sort is much the fittest for burning into lime; but that of the fat and unctuous kind by far the best to be used in the crude state.

It has been stated that in some parts of Essex they lay from five to eight waggon loads of chalk on an acre, either upon a clover lay while feeding, or on a summer fallow; and that the effect of a very thin dressing of it is seen immediately to an inch, like that of rotten dung, and lasts twenty years, fifteen in good heart. The soil is a loam; they have also a little clay, and no sand: on gravels the effect is but slight. They bring the chalk from Malden, whither it is brought by sea from Kent, and a waggon load costs mostly ten shillings at the quay. It is rather hard; the sharpest frosts leave many lumps unbroken; these they break with pick-axes. The effervescence with vinegar is pretty considerable, but in water it scarcely falls at all. It is also a general opinion in that county, that land which has been once chalked will not take it again; they acknowledge, however, that when mixed with earth and dung it is then excellent. They observe, that laying a slight dressing of chalk and earth, or dung, on a field never chalked, will take so much effect, that the same field will not answer to chalk completely. They observe also, that the chalk presently gives the land a red colour. And they are of opinion, that chalk is a great enemy to good grass; and affirm, that a field which, before chalking, will run of itself to a fine head of white clover, no longer does it after chalking.

There is no saying any thing against experience: we should not, however, draw general conclusions from partial experiments. Much of the effect of manures depends upon the soil on which they are laid. About Enfield, as observed in a paper in the *Annals of Agriculture*, the same chalk does wonders, which at North Mims has very little effect: the one is a rich loam, the other a poor gravel. And near Sandwich, in Kent, chalk has been found in a very high degree to improve a sandy soil, giving it tenacity, and totally exterminating that pernicious weed the corn marigold, which is provincially called *yellow bottle*, *buddle*, or *golfs*, and so abundant in sandy soils. They lay on forty loads of forty bushels each to an acre. Upon pasture land they think it does nothing. In Hertfordshire it is thought that chalk makes the land plough much better, and renders all manures much more effectual. If a field be divided into parts, one chalked, a second chalked and manured with dung or soot, ashes, &c. and a third dunged or ashed without chalk; although chalk alone has no effect, yet the other manure on the chalked part will have a much greater effect than on the part where no chalk is laid. Facts of this sort are highly interesting, but want to be more correctly made.

It has been remarked by the author of the *Synopsis of Husbandry*, who has had much experience in a district where it abounds, that this manure, though it falls infinitely short of marl in its fertilizing quality, is nevertheless possessed of virtues which deservedly entitle it to the esteem of the farmer. By a proper application of this substance, the most tenacious clays are, he says, rendered friable and mellow; and thus, their native stubbornness and adhesion being overcome, the several particles of the soil are enabled to imbibe the full benefit of the different changes of the atmosphere; and hence they are brought to work kindly under the several operations of the plough, harrow, &c. and to produce ample crops of grass or corn, which, before the application of this manure, they were incapable of bringing to perfection. So great are the benefits accruing from this manure, when laid on a stiff clayey soil, that the Essex farmers find their account in freighting barges from the chalk cliffs in Kent, and afterwards carrying it with their teams several miles up the country; all which, though attended with a heavy expence, is found to answer the purpose extremely well, as it would, he thinks, be impossible to reduce these stubborn clays to a proper tilth without the previous application of this manure. Nor is it on clays only where chalk may be laid to advantage: gravels, especially those which lie near the springs, and all wet soils, may, he supposes, be dressed with this manure, which will never fail to meliorate and sweeten the ground, and enable it to retain longer the virtues of the dung that may be applied, which, on these hungry soils, is liable to disappear in a short time: nay, so partial are some farmers to the use of this manure, that he has known it carried on soils where the chalk lay within a few inches of the surface.

It has been stated, that the action of chalk on the soil is either chemical or mechanical. It acts chemically as an absorbent, contributing to preserve dry those lands which are poachy and wet; and by its attraction for acids it may hasten the putrefaction of vegetables. It acts mechanically, by entering into the composition, and totally altering the nature of clay, converting it by proper pulverization into a species of marl. By insinuating itself between the particles of clay, it destroys their adhesion; thus preventing it from becoming too hard in summer, and too wet in the winter season.

It is observed by Mr. Bannister that there are two methods of obtaining chalk. The first is by uncallowing a piece of

ground, and making it convenient for a pit, where the carts may be drawn into it, and filled: this is on a presumption that the chalk lies near the surface, and that the pit is within a small distance of the field on which the manure is to be laid. The other method is to sink pits in the field where the chalk is intended to be laid as a manure, and which, in his opinion, is far preferable to that of drawing it in carts as before mentioned. In this case, a number of pits are to be sunk according to the extent of the field. These pits are to be made in the form and circumference of a well, with an apparatus at the top, and a bucket to draw up the chalk. The people who undertake this business, having been brought up to it from their infancy, perform it, he says, with great facility, and without any tardity, though attended with much danger. A person is employed at the top to draw up the contents of the pit, shoot the chalk into the cart, and wheel the same on the land. When the labourer has arrived at the chalk, which takes up a longer or less interval of time according to the depth at which it lies, and has dug some little time therein in the perpendicular form wherein he began the pit, he proceeds to form apertures in different horizontal directions; so that where the chalk is good, and the pit stands firm, large tracts of ground are undermined for this purpose. The price for digging chalk is, he says, 1s. per foot till the chalk be found, after which for the chalk 1s. per load, which is twelve baskets; and a penny per load for wheeling the chalk on the land, the farmer providing a horse and cart for that purpose. The quantity usually laid on an acre is from eighty to a hundred loads.

From this description of chalk drawing, he says, "it is evident that much care and circumspection are required to prevent any deceit being imposed on the farmer by the workmen, to which their eagerness of acquiring large wages will be a powerful inducement."

He adds, that "the best chalk is that which is white and hard; and the deeper it lies beneath the surface, the more efficacious is the dressing supposed to be, as partaking less of the nature of the soil whereon it is to be applied as a manure; indeed on a clayey soil it is seldom to be met with, but at a considerable distance beneath the surface of the field. The most eligible season, he says, for the performance of this work is in the early part of the winter, as the chalk which is laid out at that season will, by aid of the succeeding frosts, be, in a great measure, meliorated and reduced to crumbs at the time of following in April; whereas, should the business be deferred till the spring, no inconsiderable portion of the chalk will remain in lumps till the next winter. From this neglect, a twelvemonth will be lost in point of time, as this manure will lie on the ground without answering any good purpose till the lumps shall have been slackened by moisture and frosts; and that chalk is always most highly esteemed which yields soonest to the effect of the weather in falling into crumbs. This manure may be laid on the ground in the summer, without any other inconvenience than what has been before mentioned; contrary to the opinion of some people, who think that such chalk, having remained on the surface during the summer months without rurning, will, on that account, be less susceptible of the frosts in the succeeding winter: but this idea is erroneous; and as it may often suit the economy of the farmer to lay this chalk out in the summer, either from a neighbouring draw-pit, having at that time little other employment for two men and horses, or if he may be inclined to sink a pit in the field at that time; in either of these contingencies, the business may, he thinks, be safely ventured upon in that season; and it would be far better to suffer the ground, which is thus summer chalked, to lie unploughed till the succeeding spring, than

to crop it with wheat at the autumn after the manure is applied; for, having enjoyed the benefit of the frosts in the following winter, the ground will come in properly for a wheat season in the next year: and this may be generally effected, he says, where a person is inclined to lay on his chalk in the summer. For instance, suppose a lay ground be intended for a fallow the next year, this may be chalked in the summer time, with very little inconvenience or injury to the farmer, as the grass which would have been produced from it between midsummer and the following spring could have turned to little account."

It is conceived by the same writer, "that when land is dressed with chalk, the surface ought to be pretty thickly covered over, otherwise it will fail to answer the end of pulverization, in which consists the chief virtue of this manure: and though the expence of chalking may appear considerable to those who are unacquainted with its effects, the good consequences accruing to the future crops will be found in the end amply to compensate the primary charges, and from whatever cause this improvement arises, whether an immediate fertility be conveyed to the soil by the chalk, or whether this dressing acts on the soil by destroying its adhesion, and thus disposes it to work more kindly, and to part with its vegetative particles, which were before so closely united as not to be drawn forth by any other means: in whichever of these ways the chalk acts upon the land it matters, he thinks, very little to the farmer, so that the intention be accomplished, namely, the acquisition of a more abundant crop. For his own part, he is inclined to think that the chief virtue of the chalk resides in its power of correcting the adhesion of stiff soils, and in its meliorating quality, and that it is much inferior to dung, in point of accelerating the growth of the crop; so that where a field has been well dressed with this manure, which is said to be of so lasting a nature as to shew its good effects at the distance of twenty years, it is by no means to be understood, that this field is not to be dunged, or to have any further addition of manure during this interval: on the contrary, such ground ought never to lose its turn of the dung-cart; and, indeed, on farms of a clayey soil, those fields only can be dunged to advantage which have been previously chalked; for experience hath demonstrated, that, without the application of this manure, dung will be of but small avail on these stiff soils."

It is remarked further by the same practical writer, "that on gravelly soils, where the springs lie within a small distance of the surface, it often happens that the water flows in before the chalk is found, and thus all further endeavours at that spot are rendered abortive, and another pit must be sunk in a different part of the field. Obstacles to this work sometimes, he says, fall out from the light texture of the soil, which does not unfrequently give way to the destruction of the chalk-drawer. To the farmer, it may be of some consequence to consider the nature of his land, ere he embarks in this scheme of husbandry; as, if from circumstances above-mentioned, he may have reason to think that his pit will not stand firm, it would be a matter of prudence to desist from any further thoughts of sinking a perpendicular pit, and change the mode of operation, by bringing his chalk from an uncalled pit: but where it can be obtained at a moderate expence, and with a tolerable certainty of success, the preceding method is, he thinks, certainly the most eligible." See *Calcareous Earth, and Manure*.

In the chalking of land, the method pursued in Herefordshire, where the persons employed in it follow it as a trade, is the following, according to Mr. Walker: "a spot is fixed upon, nearly central to about six acres of land,

to be chalked. Here a pit, about four feet in diameter, is sunk to the chalk, if found within twenty feet from the surface; if not, the chalkers consider that they are on an earth pillar, fill up the pit, and sink in fresh places, till their labour is attended with better success. The pit from the surface to the chalk is kept from falling in by a sort of basket-work, made with hazel or willow rods and brushwood, cut green and manufactured with the small boughs and leaves remaining thereon, to make the basket-work the closer. The earth and chalk are raised from the pit by a *jack-rowl* on a frame, generally of very simple and rude construction. To one end of the rowl is fixed a cart wheel, which answers the double purpose of a fly and a stop. An inch rope of sufficient length is wound round the rowl, to one end of which is fixed a weight, which nearly counterbalances the empty basket fastened to the other end. This apology for an *axis in peritrochio*, two wheelbarrows, a spade, a shovel, and a pick-axe are all the necessary implements in the trade of a company of chalkers, generally three in number. The pit-man digs the chalk and fills the basket, and his companions alternately wind it up and wheel its contents upon the land; when the basket is wound up to the top of the pit, to stop its descent till emptied, the point of a wooden peg, of sufficient length and strength, is thrust by the perpendicular spoke in the wheel into a hole made in the adjoining upright standard of the frame to receive it. The pit is sunk from 20 to 30 feet deep, and then chambered at the bottom; that is, the pit-man digs or ruts out the chalk horizontally, in three separate directions; the horizontal apertures being of sufficient height and width to admit of the pit-man's working in them with ease and safety. One pit will chalk six acres, laying 60 loads on an acre. If more be laid on, and to the full extent of chalking, viz. 100 loads, then a proportionable less extent of land than six acres is chalked from one pit. Eighteen barrow-fuls make a load, and the usual price for chalking is 7d. per load, all expences included; therefore the expence of chalking at 60 loads per acre is *1l. 12s. 6d.*; and at 100 ditto, *2l. 18s. 4d.* As the chalk is considered to be better the deeper it lies, and the top chalk, particularly if it be within three or four feet from the surface, very indifferent, and only fit for lime, or to be laid on roads, gateways, &c. the chalkers must be directed to lay by the chalk for the first three or four feet in depth, to be applied

to the above purposes; or, if not wanted, to be again thrown into the pit when filled up; and also to pick out the flints from the chalk before it is carried on the land, for, if they are not narrowly watched, they will chalk with both."

It is added, that "Mr. John Hill of Coddicott farms upwards of 1200 acres in the adjoining parishes of Coddicott and Kimpton, a considerable part of which is his own estate. He has chalked many acres of land, and approves much of the practice. He chalked a field of strong clay land in the autumn of 1793, laid on sixty loads to an acre, and the chalk where the pits were sunk lay about ten feet from the surface. Mr. Walker viewed the field the 7th of August 1794; it had borne a crop of peas since it was chalked, and was then under the plough, preparatory for a crop of wheat. The chalk was good, and the land appeared to work well, though the chalk was not then thoroughly incorporated with the soil. Mr. Hill never lays more than 60 loads of chalk on an acre; this he finds will not only make the land work much better, with less strength of cattle, but also, with a light coat of dung, or spring dressings occasionally laid on to quicken the vegetation, produce abundant crops for ten years; he then chalks again with equal success."

This sort of work should proceed with dispatch during the summer months in *all* cases, and in the autumnal ones in many situations where there is no danger of poaching the ground. Mr. Young suggests, that much advantage may be derived, in performing this sort of business, from the use of small three-wheeled carts, as the third wheel affords a support for the cart and load while filling, without the fill horse, and of course one horse may be sufficient for two carts, one being discharged upon the land while the other is loading. See MANURE.

CHALK, *black*. See SLATE.

CHALK, *brown*. See TRIPOLI.

CHALK, *French*. See STEATITE.

CHALK, *fungous*. See AGARIC *mineral*.

CHALK, *red*. See Ores of IRON.

CHALK, *silver*. See AGARIC *mineral* and ARGENTARIA *creta*.

CHALK, *Spanish*. See STEATITE.

CHALK, *yellow*. See TRIPOLI.

CHALK-drawings. See DRAWING and ENGRAVING.

Charcoal

CHARCOAL, in *Chemistry*. Under the article **CARBON** are mentioned the chemical properties of charcoal; nothing further therefore remains to be described except the method of preparing the substance and a few other particulars intimately dependent upon it.

Charcoal is prepared either by burning or distillation; of these the first is the simplest, most ancient, and usual method, on which account we shall begin with it.

The business of charcoal burning takes place during the whole of the summer months, and is for the most part carried on in the woods to save the expence of carriage. Two or three families commonly unite for this purpose, dwelling in tents or temporary huts during the time in which they are thus employed for the convenience of being near their business. After they have felled the timber, and it is become sufficiently dry, the process of converting it into charcoal is begun by raising a plot of ground a little higher than the surrounding surface, and bringing it to a slightly convex form by beating it, and thus forming a hard, dry, and solid floor. In the center of this area is placed a circle of sticks adjoining each other and composing a vertical hollow cylinder from three to four inches in diameter, and about six feet high. Round this interior cylinder are ranged successive concentric circles formed by truncheons from one to ten inches in diameter, care being taken that the truncheons in any one circle are of the same diameter, and that one built of the largest wood be always succeeded by one of the smallest wood, in order that there may be as few interstices as possible. The outermost circle is composed of brush-wood. When the pile measures from twenty to thirty feet in diameter, it is sufficiently large; a coating is now laid on of turf, the grassy side next to the wood, and dry earth is heaped up round the bottom of the pile, and well rammed in order to prevent the admission of air. Three or four screens formed of large hurdles well stuffed with brushwood, are also prepared in order to protect the pile from the violence of the wind. All the preparations being now completed, the pile is kindled by dropping lighted chips down the hollow cylinder in the center, which, in proportion as they are consumed, are supplied by others during the first three or four days, at the end of which period, the kindling of the pile is completed. The top of the cylinder is now closed, and a row of holes, each about two inches in diameter, is pierced at the

base of the pile, by which the requisite quantity of air is supplied, and a passage is afforded for the smoke and vapours. When the smoke nearly ceases to issue from these holes, a second row is opened, about six or eight inches above the first, which are now closed; in this manner the fire is conducted to the top of the pile in about a fortnight; at which time the pile is covered up with earth as accurately as possible, till the fire is completely extinguished. Those pieces that are found not to be sufficiently charred are called *brands*, and are employed as fuel for the next fire.

Although charcoal prepared by the above method is fully adequate to all the purposes of fuel to which this substance is applied, yet in the manufacture of gunpowder, and for some other uses, it is of essential importance to procure a charcoal of greater purity than common. This was formerly done by selecting the stems of willow, alder, and some other of the aquatic trees, and charring them in the usual manner, but with peculiar care. Of late, however, a considerable improvement in the preparation of the finer charcoal has taken place, by charring or distilling the wood in closed iron cylinders. For this purpose a large cylinder of cast iron fixed in masonry over a grate, and furnished at one end with a door capable of being accurately closed, and terminating at the other in a curved pipe, is filled with the chips of any kind of wood; the door being then closed, and a fire lighted in the grate, the empyreumatic acid and all the other volatile parts of the wood are driven off by the heat, which is increased till the contents of the cylinder are red hot. The fire is then withdrawn, the cylinder is allowed to cool, and a black shining and remarkably pure charcoal (in greater proportion also to the quantity of wood employed than by the usual way) is procured, admirably fitted for the use of the gunpowder-makers, and apparently possessed of the same qualities from whatever kind of wood it is made.

The proportion of charcoal yielded by particular woods is liable to be so materially affected by the age, and the dryness of the wood, as to render it almost impossible to obtain any correct result in the great way. The following table, from experiments in the small way by Mr. Musket, will, however, be found to be interesting, as all the woods before being charred were thoroughly dried and prepared, as nearly as possible in the same circumstances.

100 Parts of Lignum vitæ afforded	26.0	of Charcoal of a greyish colour resembling coak
Mahogany	25.4	tinged with brown, spongy and porous
Laburnum	24.5	velvet black, compact, very hard
Chestnut	23.2	glossy black, compact, firm
Oak	22.6	black, close, very firm
Holly	19.9	dull black, loose and bulky
Sycamore	19.7	fine black, bulky, moderately firm
Walnut	20.6	dull black, close, firm
Beech	19.9	dull black, spongy, firm
Norway pine	19.2	shining black, bulky, very soft
Elm	19.5	fine black, moderately firm
Sallow	18.4	velvet black, bulky, loose and soft
Ash	17.9	shining black, spongy, firm
Birch	17.4	velvet black, bulky, firm
Scottish pine	16.4	tinged with brown, moderately firm

The author of the Rural Economy of the midland counties observes, that in making charcoal, men accustomed to the business cut and cord in wood in the winter, and burn during the summer season. The minutiae of the process of which are there, he says, these. The site, or hearth, being determined upon, the sward is pared off, and the sods laid on one side. The wood usually about the cord is then laid in a ring, somewhat wider than the intended hearth; beginning on the outer circumference of the ring with the smallest of the round-wood, laying the larger pieces of top-wood, and the cloven roots, or but-ends, towards the center. With these last, some of them nearly as large as bushel blocks, they begin to make their pile, leaving a kind of chimney in the middle, (a vertical aperture, from a foot to eighteen inches wide), and round this core of roots set up the top-wood, (which has previously been cut at the time of cording, in such a manner, that no forkedness or other awkward crookednesses are left; or, if not cut in this manner, or cut improperly, it is prepared by the colliers themselves, previous to laying it ready for setting), joining the blocks, or rather fitting them in, as close to each other as possible; placing the convex side of the logs outward, forming the pile in the shape of an inverted bowl, nearly semiglobular. The pile being formed, it is covered over with sods, which are pointed, to keep in the heat the better, and the seams are filled up with fine pulverised mould. The chimney is now filled with short pieces of dry wood; near the top a live coal is put; over this one layer more of dry pieces; and upon these a close cap of sod is placed: nevertheless, this one coal, not larger than the fist, and excluded from the open air, is sufficient to set the whole pile on fire. As the pieces in the chimney burn away, they are replaced by fresh ones: thus feeding the fire with fresh fuel. Paled hurdles are placed on the windward side of the heap, to prevent the fire from acting partially.

When the fire begins to work itself out, at the outward skirts of the bottom of the pile, it is known that the coal is fully burnt, (or rather the wood sufficiently charred), which it will be, in a pile of ten cord, in fine dry weather, in seven or eight days. The fire, during the whole time, is carefully kept from breaking out, by throwing mould or ashes upon the weak parts: so that, though the fire passes through every part of the wood, little or none of the matter of heat escapes. It is observable, he says, that notwithstanding the intense heat, no part seems to be consumed; not the bark only, but even the moss upon it, comes out as entire as when it went in: the only apparent change is, in its being rendered friable and of a black colour. Wood that is charred, seems, he says, to be only very highly dried. It shrinks considerably during the process of charring; but there is no visible derangement of parts. One of the smaller pieces, which is not broken in the drawing, appears as entire when it comes out as when it went into the pile. The brittleness after charring, however, shows that the texture of the wood is altered by the action of the fire. As soon as the fire is out of the coal, on the outside of the heap, the workmen begin to draw; which is done by running a peel between the coal and the hearth, raising up the coal in such a manner as to let the mould and ashes of the sods fall through between the pieces, upon the inward parts, still full of fire. If this makes its appearance in any particular spot, a peel full of ashes is immediately thrown against it. Having got sufficiently near to the fire, the coals raised by the peel are raked off with long, wide-toothed, iron rakes; the teeth about a foot long, and standing about six inches apart; the handle and head of wood, except a plate of iron on the back, with which the small coal is gathered together. No sieve, nor any rake with finer teeth than the above, is used.

The coal being light, it is readily brought to the surface of the ashes and dirt; and, when there, is easily collected with the back of the rake. The side, thus drawn, being rounded up and secured with ashes, another, the coolest part, is drawn in the same manner. The drawing is an infernal business: the men working among fire and heat enough to suffocate Satan himself. Such pieces as still retain fire, after they are drawn, are quenched with water; which the workmen have in plenty standing by them, in pails. If a large piece contain much fire, (which hides itself chiefly in the chinks of the large pieces), it is plunged bodily into the water. If the heap itself prove too refractory to be kept under by the ashes alone, a sufficient quantity of water is thrown upon it, to keep the fire under. Such large pieces as are suspicious are laid on one side, in order that those which take fire may be the more readily discovered. A waggon attends to take away the coal as fast as it is drawn: for, if it take fire, or get wet in the hands of the burners, it is at their risk; and, while in the waggon, it is at the risk of the waggoner. Every particle burnt is so much entire waste.

The quantity of ashes arising from a charcoal hearth, he says, is considerable. There were four cart loads taken up from two small hearths, and a load or two more still remained.

The dust of charcoal has been found, by repeated experience, to be of great benefit to land, especially to such soils as are stiff and sour. It is to be used in the same manner as foot and wood-ashes. See ASHES and SOOT.

And the author quoted above observes, that charcoal ashes are in good esteem in the midland districts as a manure, particularly for turnips, and for fining grass land. They arise principally from the sods used in covering, but in part from the bits of coal which break off in raking it out of the ashes. There cannot be any doubt but that all the refuse of charred materials that become reduced into a powdery state during the process of drawing the coal, is highly beneficial, when applied on the more stiff and heavy sort of land as a manure, as much advantage has been derived from it in the experience of different cultivators.

The microscope discovers a surprising number of pores in charcoal: they are disposed in order, and traverse it lengthwise; so that there is no piece of charcoal, how long soever, but may be easily blown through. If a piece be broken pretty short, it may be seen through with a microscope. In a range the eighteenth part of an inch long, Dr. Hook reckoned one hundred and fifty pores; whence he concludes, that in a charcoal of an inch diameter, there are no less than five millions seven hundred and twenty-four thousand pores.

It is to this prodigious number of pores that the blackness of charcoal is owing: for the rays of light, striking on the charcoal, are received and absorbed in its pores, instead of being reflected; whence the body must of necessity appear black, blackness in a body being no more than a want of reflection.

Mathematical instrument makers, engravers, &c. find charcoal of great use to polish their brass and copper plates, after they have been rubbed clean with powdered pumice-stone. Mr. Boyle says, that the more curious burn it a second time, and quench it in a convenient fluid. Plates of horn are polishable the same way, and a gloss may be afterwards given with tripoly.

Charcoal and soot-black are the two most durable and useful blacks of the painter, and the varnish-maker. Those of the former kind are used both as pigments and pencils; and charcoal crayons prepared from the willow are preferred on account of their softness. See concerning them Lewis's *Commercium Phil. Techn.* p. 536.

Charcoal tinges glass in fusion yellow, reddish, &c. and by baking stains it yellow. See *ibid.* p. 628. See also his observations on the differences of different charcoals, &c. and of the manner of distinguishing between the vegetable and animal, *ibid.* p. 336. and seq.

Charcoal was anciently used to distinguish the bounds of estates and inheritances; as being supposed incorruptible, when let very deep within the ground. In effect, it pre-

serves itself so long, that there are many pieces found entire in the ancient tombs of the northern nations.

M. Dodart says, there is sometimes found charcoal made of corn, probably as old as the days of Cæsar: he adds, that it has kept so well, that the wheat may be still distinguished from the rye; which he looks on as a proof of its incorruptibility.

Chipping

CHIPPING, in the *Manufactures*, a term used by the potters and china-men to express that common accident both of our own stone and earthen ware, and the porcelain of China, the flying off of small pieces, or breaking at the edges. Our earthen wares are particularly subject to this, and are always spoiled by it before any other flaw appears in them. Our stone wares escape it better than these, but less than the porcelain of China, which is less subject to it than any other manufacture in the world. The method by which the Chinese defend their ware from this accident, is this: they carefully burn some small bamboo canes to a sort of charcoal, which is very light, and very black; this they reduce to a fine powder, and then mix into a thin paste, with some of the varnish which they use for their ware: they next take the vessels when dried, and not yet baked, to the wheel, and turning them softly round, they, with a pencil dipt in this paste, cover the whole circumference with a thin coat of it: after this, the vessel is again dried; and the border made with this paste appears of a pale greyish colour when it is thoroughly dry. They work on it afterwards in the common way, covering both this edge and the rest of the vessel with the common varnish. When the whole is baked on, the colour given by the ashes disappears, and the edges are as white as any other part; only when the baking has not been sufficient, or the edges have not been covered with the second varnishing, we sometimes find a dusky edge, as in some of the ordinary thick tea-cups.

It may be a great advantage to our English manufactures to attempt something of this kind. The willow is known to make a very light and black charcoal; but the elder,

though a thing seldom used, greatly exceeds it. The young green shoots of this shrub, which are almost all pith, make the lightest and the blackest of all charcoal; this readily mixes with any liquid, and might be easily used in the same way that the Chinese use the charcoal of the bamboo cane, which is a light hollow vegetable, more resembling the elder shoots than any other English plant. It is no wonder that the fixed salt and oil contained in this charcoal should be able to penetrate the yet raw edges of the ware, and to give them in the subsequent baking a somewhat different degree of vitrification from the other parts of the vessel, which, though if given to the whole, it might take off from the true semivitrified state of that ware; yet at the edges is not to be regarded, and only serves to defend them from common accidents, and keep them entire.

The Chinese use two cautions in this application: the first in the preparation; the second in the laying of it on. They prepare the bamboo canes for burning into charcoal, by peeling off the rind. This might easily be done with our elder shoots, which are so succulent, that the bark strips off with a touch. The Chinese say that if this is not done with their bamboo, the edges touched with the paste will burst in the baking: this does not seem indeed very probable; but the charcoal will certainly be lighter made from the peeled sticks, and this is a known advantage. The other caution is, never to touch the vessel with hands that have any greasy or fatty substance about them; for if this is done, they always find the vessel crack in that place. *Obs. sur les Cout. de l'Asie.*

Clay

CLAY. In common language, any earth which possesses sufficient ductility when kneaded up with water to be fashioned like paste by the hand, or the potter's lathe, is called a *clay*. In *Mineralogy*, however, the term has a somewhat more extended application, comprehending not only the proper ductile clays, but certain other mineral substances which bear a strong analogy to them. They may be conveniently arranged under the five following sub-species.

1. Subsp. *Pure clay*.—*Reinethon Erde*, Germ.—*Lac Luna* of some authors.

Its colour is snow-white or yellowish-white. It occurs in small kidney-shaped pieces. It is without lustre; its fracture is fine earthy; it is opaque; stains the fingers slightly; adheres feebly to the tongue; is fine but meagre to the touch; is very light, soft, and easily frangible. Its component parts, according to a recent analysis by Fourcroy, are,

45	alumina
24	fulphated lime
27	water
4	lime and silice.

100

It has hitherto been found only at Halle in Saxony, where it occurs very near the surface, and accompanied by gypsum.

2. Subsp. *Porcelain clay*.—*Porzellauerde*, Germ.

Its colour is reddish-white, passing to yellowish and greyish-white. It occurs in mass and disseminated. It stains the fingers; is for the most part slightly coherent, passing into dusty; is fine but meagre to the touch; slightly adheres to the tongue, and is but of little specific gravity.

A specimen, analysed by Vauquelin, afforded the following result:

55	silice
27	alumina
0.5	oxyd of iron
2	lime
14	water

98.5

When perfectly pure, it is nearly, if not entirely, fusible in the greatest heat of a porcelain furnace.

It forms beds in geiss, and not unfrequently occurs in granite, occupying the place of the felspar: indeed, it may readily be traced through various states of induration into true felspar; hence it has been considered by some as decomposed felspar, and by others as unformed or imperfect felspar.

The clay employed in the manufacture of the Berlin porcelain, is procured from the district of Magdeburg: the best French porcelain clay (the subject of the above analysis) is dug near Limoges; and the best English porcelain clay is procured from Cornwall: this latter is naturally mixed with quartz and mica, forming a granite, from both of which it is separated by washing.

3. Subsp. *Common clay*.—*Potter's clay*.—*Pipe clay*.

Its colour is very various; when greyish-white it is called *pipe clay*; it also occurs greenish-grey, passing into verdigris-green; smoke-grey, passing into yellowish-brown; reddish-brown and brownish-red; or, lastly, bluish-grey, passing into blackish-blue. It occurs massive, or fine slaty, forming veins or beds; these latter, often of great extent and thickness. Its fracture is earthy, passing into uneven or imperfectly conchoidal. It is generally smooth, and somewhat unctuous to the touch; adheres pretty strongly to the tongue, is soft and easily frangible.

When in veins, it generally occurs in primitive mountains, accompanying metallic ores; when in beds, it is usually found in alluvial land, covered by or resting on gravel.

It consists essentially of alumina and silice, but generally contains, besides, a variable proportion of oxyd of iron. Carbonated lime, too, is by no means an unfrequent ingredient, and when this abounds, the clay passes into marl. See **MARL**.

4. Subsp. *Indurated clay*.—*Clay-stone*.

Its colours are greenish-grey, bluish, ash, smoke, and pearl-grey, or brownish-red. It occurs in mass; is opaque and without lustre. Its fracture is fine grained earthy, passing into slaty, splintering, and imperfectly conchoidal. It adheres but slightly to the tongue; is soft and easily frangible.

When put into water, it falls to pieces by degrees, but even then possesses very little ductility. It occurs in rock masses, in veins and beds, and forms the basis of clay porphyry. It passes, on the one hand, into potter's clay, and, on the other, into jasper.

5. Subsp. *Shale*.

Its colour is smoke-grey, yellowish, ash, or bluish-grey, or greyish-black. It occurs in mass. It is dull, but when mixed with mica is glimmering. Its fracture is slaty, approaching sometimes to earthy. It is opaque, soft, and easily frangible; it is meagre to the touch, adheres slightly to the tongue. Sp. gr. about 2.6.

It occurs in the independent coal formation, also in the most recent floetz trap and alluvial formations.

It generally breaks down when put into water, and by exposure to the weather it decomposes into a very unctuous and tenacious clay.

Of the above sub-species, the first, on account of its rarity, is made no use of. The second is the basis of the European porcelains, for which it is well adapted, on account of its difficult fusibility, and its hardness and compactness of texture when baked; it is even less fusible than felspar, from the decomposition of which, in particular cases, it certainly originates: but felspar contains a very notable proportion of pot-ash, which disappears during its decomposition, being probably washed away; and to this, no doubt, is owing the greater infusibility of the clay.

The method of ascertaining the goodness of porcelain clay is to knead it into a mass with water, and after having dried it very gradually and thoroughly, to expose it to a full white heat in a muffle; if, after being thus baked, its colour is a pure white, if its texture is compact and porcellaneous, and it exhibits no signs of fusion, it may be considered as of the very best quality: but as it generally contains a variable proportion of iron, so its colour will exhibit more or less of a reddish-yellow tinge; and as this prevails, so the value of the clay will be materially impaired. A slight ashery tinge

may be got rid of in the manufacture, by the addition of a little smalt; but the ware thus acquires a bluish tinge, which, though not very perceptible alone, is sufficiently obvious when compared with porcelain made of pure unfossilified clay.

The common clays, or those that belong to the third sub-species, may be divided, with regard to their utility, into the three classes of unctuous, meagre, and calcareous.

The unctuous contains, in general, more alumine than the meagre, and the siliceous ingredient is in finer grains: when burnt, it adheres strongly to the tongue, but its texture is not visibly porous. When containing little or no oxyd of iron, it burns to a very good white colour, and is very infusible; pipes are made of it, and it forms the basis of the white Staffordshire ware. If it contains oxyd of iron, or pyrites, sufficient to colour it red when baked (as is usually the case), it becomes much more fusible, and can only be employed in manufacturing the coarser kinds of pottery.

Meagre clay is such as when dry does not take a polish from rubbing it with the nail: it feels gritty between the teeth, and the sand which it contains is in visible grains. When burnt without addition, it has a coarse granular texture, and is employed in the manufacture of bricks and tiles.

Calcareous clay effervesces with acids, is unctuous to the touch, and always contains iron enough to give it a red colour when baked. It is much more fusible than any of the preceding, and is only employed in brick-making: by judicious burning it may be made to assume a semi-vitreous texture, and bricks thus made are very durable.

Any of the unctuous or meagre clays, that are very infusible and contain but little iron, may be employed in making crucibles, and other similar chemical vessels, that are required to stand a powerful heat.

CLAY, in *Agriculture*, a soft, earthy substance, of an unctuous and tenacious quality, and which is found in a native state in different situations. It has been remarked by Dr. Fordyce, to form a tenacious mass when mixed with water, which hardens upon drying, and does not diffuse so readily in water again as sand; and that if a mass of it be heated red hot, it becomes hard, and burns to a brick, resembling crystalline earth in its properties. It is also found that soap-earth agrees in its properties with clay, of which it is a species, only it is much more diffusible in water, separates from it with greater difficulty, is of a smoother texture, and has finer particles. It is a substance that by culture becomes more diffusible in water. The earth or soil consists chiefly of strata of substances, in which the clay and crystalline earth are sometimes found pure, but more commonly there is a mixture of the two; and it is seldom that pure clay is found than pure sand. It has been remarked by Lord Dundonald, that this kind of matter forms not only a large portion of the surface-soil of most countries, but it is also found in the mineral strata to an immense depth; that argillaceous matter, or clay, is no where found pure, but is more or less adulterated with other earths, and with different materials, such as mineral, vegetable, and animal substances. And that the purest clay contains upwards of sixty per cent. of siliceous matter, or sand.

It is the earth most retentive of moisture, by which it becomes ductile and tenacious, and loses these properties by the action of fire, or by being burnt. According to Mr. Kirwan, it is of various colours, as white, grey, brownish red, brownish black, yellow, or bluish; it feels smooth, and somewhat unctuous; if moist, it adheres to the fingers, and if sufficiently so, it becomes tough and ductile. If dry, it adheres more or less to the tongue; if thrown into water, it gradually diffuses itself through it, and slowly separates from it. It does not usually effervesce with acids, unless a strong heat be applied, or that it contains a few calcareous parti-

cles, or magnesia. It consists of argill and fine sand usually of the siliceous kind, in various proportions, and more or less ferruginous matter. The argill, according to him, forms generally from 20 to 75 per cent. of the whole mass; the sand and calx of iron the remainder. These are perfectly separable by boiling in strong vitriolic acid.

It is remarked by Dr. Darwin, in his "*Philosophy of Agriculture and Gardening*," that the too great adhesion of the particles of argillaceous earth, or clay, renders it, in its pure state, unfit for vegetation; as the tender fibrils of roots can with difficulty penetrate it; whence it becomes much improved for the purposes of agriculture, when it is mixed with calcareous earth and with siliceous sand, as in marl. It is commonly believed, he also says, that lumps of clay become meliorated by being exposed to frost in its moist state, which, by expanding the water which it contains, by converting it into ice, is supposed to leave the particles of the clay further from each other. This, however, he says, seems in general to be a mistaken idea, since, if the act of freezing seems to occur, as noticed by Mr. Kirwan in his "*Mineralogy*," vol. i. p. 9, who observes, that clay, in its usual state of dryness, can absorb two and a half times its weight of water without suffering any to drop out, and retains it in the open air more pertinaciously than other earths, squeezing out its water, and thus parting with more of it than other earths. This curious circumstance, that water as it crystallizes detaches the clay which is diffused in it, corresponds, he remarks, with other facts of congelation. Thus when wine, or vinegar, or common salt and water are thus exposed to frosty air, the alcohol, the acetic acid, the marine salt, and the calx of copper, are all of them detached from the aqueous crystals, and retreat to the central part of the fluid, or to that last frozen, or into numerous cells surrounded with partitions of ice, as he has frequently observed; whence it appears, that wet clay is in general rendered more solid and tenacious by being frozen, as well as when it is dried, and its moisture exhaled by too warm a sun, and by both those circumstances becomes less adapted to the purposes of agriculture. In most clays a kind of effervescence occurs, after they are turned over and thrown on heaps, and thus acquire air into their interstices, which renders them much fitter for the purposes of vitrification, and thus forwards the processes of the brick-kiln and pottery. This greater facility to vitrify, is probably effected by the union of oxygen with the iron, which most clays contain; as oxydes of lead and manganese are used in the more perfect vitrifications. When the clay abounds with vitriolic acid, so as to be converted into alum, it becomes very unfriendly to vegetation.

It has been found in practice, that vast improvement in many of the lighter sorts of soil may be effected by the use or application of clay upon them. And Mr. Rodwell has experienced great improvement from it on the poorer sorts of sandy soils, which are very loose, and even on black sands. See *CLAYING of Land*.

It has also been remarked by Mr. Young, in speaking of marl, that when that substance "is not to be had, clay in many places is to be found at a moderate depth. This manner has," he says, "few of the properties by which marl is to be known, but yet it works wonderful improvements on many soils. In some light lands it has been preferred by many good farmers to indifferent sorts of marl; and this preference has been the result of attentive experience. But," continues he, "the great point concerning clay, is not so much the comparison with marl, as the use of it where no marl is to be had. On all light sandy soils it should be used with a confidence of success; for the precedents of its good effects are so numerous, that we cannot have adoubt of its excellence. About sixty or seventy loads an acre, at the same

expende as of marl, will work an improvement great enough to shew how much mistaken those men are who think nothing but the finest marls worthy of attention; and upon heavier soils, as wet loams, brick earths, upon clay, and loose hollow soils, that want a firmer texture, clay is an excellent manure; but there are vast tracts of such land that cover very fine veins of clay, and yet farmers know nothing of the use of it. It is much to be regretted," he thinks, "that their landlords do not give them a juster idea, by being at the expense of claying some small fields until the benefit of the improvement becomes conspicuous."

CLAY Balls, in *Mineralogy*, are the name by which, in some places, the stony nodulous fossils called *Ludus Helmontii* are known. These are usually reckoned among the extraneous fossils, and are found of various sizes from four or five inches to almost as many feet in diameter; they are usually flattened irregularly, and appear externally, like masses of soft matter kneaded or moulded imperfectly together; their internal substance is cracked, apparently by the shrinking of their substance in drying or hardening, and the joints or septa are more or less coated or filled with spar, often of a waxy colour, whence this fossil is sometimes called *Septaria*, or *Waxen-vein*. Clay-balls are found in many of the British clay strata, and are usually lodged therein with the utmost regularity, like pavement, often touching each other, as is the case with two remarkable layers of this fossil near the top of the clay on which London stands. In the cutting of the Grand-Junction canal from Paddington towards Uxbridge, and the Croydon canal from Deptford towards Croydon, these layers were cut through and exposed in a very complete manner for examination, for great distances together; they are sunk through in all the wells near London, where the clay stratum is complete, or where none of its upper part is abraded or washed away. Sometimes a small spring of water ouzes out of these layers of clay-balls, and the same is found to possess mineral qualities, and they are, we believe, the source of most or all of the mineral springs in the immediate vicinity of the metropolis. When exposed to the air, rain, &c. clay-balls soon split, and fall into an ochry powder, and at length mix with the soil; but the spar occupying the septa is sometimes very durable, and remains entire after the substance of the ball is mouldered away. An important use was a few years ago discovered for these curious nodules, in the manufacture of a cement for water-works and stuccoing of buildings, for which Messrs. Parker and Co. of Bankside, London, have a patent; they call it Roman cement, and the same is now largely used in the construction of the walls of docks, reservoirs, &c. and for imitating stone-work in buildings; the new door-cases to the Treasury-Chambers, in Whitehall, are a specimen of the valuable qualities of this cement, the same having been applied, in very thick layers at once, during an intense frost a few winters ago, and yet it set immediately, and stands the weather as perfectly as the best stone. The front of the House of Lords, and many other buildings in Westminster, are now covering with this cement, under the direction of Mr. James Wyatt, who has applied it with effect on the new palace at Kew, and in some additions and repairs at Windsor Castle. It is not certain that all the clay-balls, lodged in the different clay strata, are exactly similar in their composition, or adapted to the manufacture of cement; where, however, they can be had in plenty, it may be worth the while of the owners of the soil to procure their analysis and trial. See *LUDUS HELMONTII*.

CLAY-Castle, in *Geography*, is situate about a mile S.W. from Youghal, in the county of Cork, Ireland, where the pieces of the bank that break off and are washed down by the sea, are by degrees petrified into a hard firm

grit. This is composed of a mixture of fine sand, and a yellow clay tempered by the sea water which beats against the hill. Wood and several other things daubed over with this clay are petrified on the spot. Smith says, there is a similar petrification at Harwich in England. Smith's Cork.

CLAY-Farms, in *Agriculture*, such as have the lands either wholly or in a great part of a clayey quality. There are many extensive tracts in different parts of the kingdom where this sort of land prevails, and which have been often cultivated to much disadvantage from the want of a due mode of cropping, and their not having of course a sufficient proportion of green winter food for the support of the requisite number of live stock, and the raising of the necessary quantity of manure. It has been suggested that these inconveniences may be fully obviated by having recourse to the cabbage husbandry. See *CABBAGE* and *FARM*.

CLAY Hill, or **COFT HEAP**, in *Geography*, a remarkable eminence on the south west branch of the grand ridge of England, about two miles W. of Warminster, and near the edge of the Chalk strata. The situation of the barrow or tumulus on the top of this hill was determined in the government trigonometrical survey in 1794, by an observation from Beacon-Hill station, distant 117,216 feet, and bearing $85^{\circ} 54' 8''$ S.E. from the parallel to the meridian of Dunnot; and another from Wingreen station distant 84,554 feet; whence is deduced its latitude $51^{\circ} 12' 13''$, and its longitude from Greenwich $2^{\circ} 13' 25''.8$ W. or $8^{\circ} 53'.7$ in time.

CLAY-Mill, a machine used by the brick-makers near London for tempering their clay. In *Plate XII. Mechanics*, are represented two of these machines. In *fig. 10*, which is the most common, A B is an upright shaft turning on a pivot at the lower end, which works in a brass socket let into a piece of wood lying on the ground; the upper end has a similar pivot, the brass is fixed in the intersection of two beams, C D, of the frame; these beams are supported by four uprights at their ends, which are firmly fixed in the ground; the whole is braced together so as to form a very steady frame for the shaft A B to turn round in. E, F, G, H, are four arms mortised in the shaft somewhat below the middle, supported by braces from the upper part of the shaft, and connected together by four braces in the form of a square; the two arms, E, F, are longer than the other two, and have hooks, by which the horses draw, fastened to them. They have also each two irons, *ab, ab*, attached to them, whose lower ends work at the sides of a circular trough or ditch, K K, which is concentric with the shaft A B, and walled with bricks. The ends of the levers, G, H, carry harrows, L, M, (*fig. 11.*) working in the same trough; these harrows are sometimes fixed to the arms, as at G, by three struts, and sometimes they are connected with the levers by four chains, and loaded with heavy weights, as at H, and better explained in the following figure.

When the machine is in use, a quantity of clay is thrown into the circular trough, K K, which is about one-fourth filled with water by a pump, the trough from which is laid under the horse-walk. The horses are then put to the ends of the levers, E, F, and set in motion; as they turn the machine round, the harrows, L, M, drag the clay round, in the trough, and by agitating it in the water, soon dissolve part of the clay, forming it into the consistence of thick mud; as the horses continue to work and more water is added, the whole mass is thoroughly incorporated; a sluice, N, is then opened which allows the clay to run out into shallow pits, which are dug in the ground at some distance round the mill, and a little below its level; in these pits the clay is suffered to remain until the greater part of the water is evaporated; it is then dug out and carried to the brick-maker. The pump

for supplying the mill, is in general worked by a man, but in the machine before us, it is worked by the mill; at the upper end of the shaft, AB, *fig. 10.* a wheel, P, is fixed, which has wooden projections nailed to it; these take the end of a lever, Q, moving on an iron bar, *d*, as a center; the weight of the lever is supported by a friction-wheel running on an horizontal bar R, fixed to the frame-work above; the lever, Q, has a rod, S, jointed to it near its end, which is supported by a frame, T, fastened to one of the upright posts, the end of this rod is jointed to one arm of a bent lever, the other arm of which has the pump-rod of the pump, O, hooked to it. As the horses turn the wheel its teeth move the end of the lever Q with it and raise the pump-rod; when the tooth quits the end of the lever the weight of the pump-rod pulls back the lever to its original position, ready for the next stroke; by this contrivance a constant supply of water is easily procured, and, by preventing the descent of the pump-rod, the pump-work is stopped when there is water enough. The iron bars, *ab, ab*, are intended to remove the clay which may get to the sides of the trough KK, and by that means escape the harrows.

The machine represented by *fig. 11*, though not so common, is much more simple in its construction. A is a stout post firmly fixed in the ground; it is hooped at top, and has a brass socket in the centre to receive the point of an iron pin, *a*, which goes through the intersection of two levers, EF, GH; this pin has a cast-iron plate, *b*, fastened to it, that is bolted to the lever, so as to connect them together. I, I, I, I, are four braces to strengthen the cross. O, O, O, O, are four other braces which carry a circular ring, R, and the whole is strengthened by four long screw bolts *d, d, d, d*; this ring fits the post loosely, and when the horse turns the machine it moves as steadily as the former machine; the harrows and the circular trough are the same. The two preceding machines are used, in those places where the clay used by the brick-makers is not very clean, but has many stones and other extraneous matter among it, as they sink to the bottom of the circular trough, and remain there when the clay is drawn off. Where the clay is naturally sufficiently pure, and requires only to be tempered, a different machine is used; it consists of a cylindric tub about three feet diameter and four feet high, in the centre of which is a vertical spindle, the lower end working in a brass socket at the bottom of the tub, the upper end turns in a collar supported by two iron bars nailed to the sides of the tub; at the top of the spindle, above this collar, a long lever is fixed for the horse to turn the spindle by; the upright spindle has six or eight arms fixed perpendicularly to it in different planes, working within the tub; these arms have spikes projecting from their upper and under sides, the tub has a small trap door in the side, near the bottom, which can be kept closed by a hasp; the clay is thrown in at the top of the tub, and the horse made to turn the spindle, the arms and the spikes fixed to it, cut the clay in every direction and mix it thoroughly, water being added in the proper quantity. When it is sufficiently ground the door at the bottom of the tub is opened, and, as the horse turns, the clay is thrown out, and carried to the brick-maker.

CLAY-Stone. See CLAY indurated.

CLAY Strata, in Mineralogy. The recurrence of clayey strata, in the sinking of deep wells, and shafts for mines, in England, is more common than those of any other matter; and since the discoveries, and meritorious labour of Mr. William Smith, on the stratification of these islands, have been known among the circle of his friends, opportunities have offered, of ascertaining the peculiarities of the organic remains most commonly lodged in these strata. In the south-eastern part of England, or uppermost parts of the series

of British strata, these are, *cornua ammonii*, *belemnites*, *corallines*, or *coralloids*, *entrochi*, *gryphites*, *bituminous wood*, &c.; at the same time that *ludus helmontii*, iron-ore, or ochre, pyrites, selenite, or gypsum, mica, &c. are not unfrequently found lodged in these clay strata.

The uppermost, or first clay stratum (or rather assemblage of clay strata) in the British series, is that on which the metropolis of the British empire and its environs stand; its upper part is red, and very tenacious when wet, forming perhaps one of the worst strata for cultivation, in England; which, but for the great population thereon, and consequent opportunities of obtaining manure, for a series of ages back, would probably, to the present day, have been in a similar state to the wastes or commons, with which the vicinity of London has been so often reproached. Near the top of this stratum, there are two remarkable layers of clay-balls, or *ludus helmontii*, as observed under the article CLAY-Ball, and lower down, pyrites, and other fossils; a layer or stratum of sand, containing black particles, occurs near the bottom of the London clay strata, which, in the sinking of wells, is sometimes found nearly dry, and at others produces a spring of unpalatable water. Beneath the London clay strata, a thick sand stratum is found, resting upon the chalk strata, and, by means of the numerous and large cracks and fissures in the chalk, the sand is supplied with a most powerfully pent or confined spring, which often rises near 250 feet, on the sinking of a well, through the clay strata above mentioned, and runs over the surface, as in Mr. Vulliamy's well, near Kensington Gravel-pits, described in the "Philosophical Transactions" for 1797, and many others in and near London, which have been sunk within a few years past. Near the bottom of the London clay strata, there are layers, or strata, of smooth, flat, and round chert pebbles, of uniform sizes, which do not appear to be worn or rounded fragments of a chert rock, but nodules, many of them consisting of concentric layers, originally formed, of the particular sizes in which we now find them.

The next clayey stratum in the British series, is found beneath the chalk strata; from its white colour, it is denominated chalk-marl in many places; when overflowed, and kept wet, by springs from the edge of the chalk strata, as at the foot of the chalk hills N. of Dunstable, this chalk-marl is very tenacious and barren; but where its out-crop is dry, as on the south side of the North Downs, near Ryegate, Godstone, &c. or the north side of the South Downs, as at Clayton, Plumpton, &c. its surface forms very good land, particularly for wheat; while the inner parts of it are, in such situations, disposed to harden into a substance almost like stone, in thin laminæ. *Cornua-ammonii*, shark's teeth, and a curious variety of extraneous fossils, are found in this chalk marl, of which we hope that the publication of Mr. Smith's intended work, will enable us to give a more detailed account, under the head of each fossil, as we arrive at the same in the progress of our work.

The next considerable assemblage of clay strata which we meet with in the British series, has a remarkable stratum of red potter's-clay on its surface, on which there is a variety of tile and pottery kilns in Sussex, beneath which a whitish tenacious clay is found, and therein a thin stratum of limestone, called Sussex marble, in many places where it is used, particularly in the slender grouped pillars of Gothic buildings, like Westminster Abbey; this thin and curious stratum of lime-stone, consists almost entirely of a congeries of turbinated, or periwinkle-like shells, of very uniform sizes; in some specimens these are all smaller than peas, and in others they are of the ordinary size of periwinkles; whether these are the produce of different beds in the same stratum, or whether a thickness of clay separates them, we have not yet been able

to ascertain. This subject we must, for the reason above stated, resume on future occasions.

The most usual vegetable productions found upon clay strata, are of the following genera; *viz.* in wet situations,

carex, *juncus*, *scirpus*, *aira*, *orchis*, *carduus*, *poterium*, *salix*, &c. while, in dry situations, the following prevail, *viz.* *primula*, *arum*, *rhinanthus*, *orchis*, *poa*, *rosa*, *rubus*, *prunus*, *acer*, *quercus*, &c.

Coal

COAL, in *Mineralogy*. The word coal has been derived by some writers from the Hebrew, and by others from the Greek or Latin, but whatever may be its origin, it is deserving of remark that the same sound for the same object is used in the Anglo-Saxon, the Teutonic, the Dutch, the Danish, and the Islandic languages. Coals are found in several parts of the continent of Europe, but the principal mines are in this country. They have been discovered and wrought in Newfoundland, Cape Breton, Canada, and in some of the provinces of New England. China abounds in them, and they are well known in Tartary, and in the island of Madagascar.

History of Coal as an Article of Commerce.

Coals are first mentioned as fuel for artificers by Theophrastus, who describes them as earthy substances that burn like wood-coals, and are used by the smiths. The ancient Britons had a primitive name for this fossil, and Pennant says, "that a flint axe, the instrument of the aborigines of our island, was discovered in a certain vein of coal in Monmouthshire, and in such a situation as to render it very accessible to the inexperienced natives, who in early times were

incapable of pursuing the seams to any great depths."

Although coals are so abundant in many of the above named places, yet as there are no beds found in the whole extent of Italy, the great line of this fuel seems to sweep round the globe, from the north-east to the south-west, visiting Brabant and France, and avoiding Italy. The strongest argument adduced by those who contend that the Romans, while in possession of this island, were ignorant of the use of coal, is, that there is no name for it in the Latin language, the word *carbo* being always used for charcoal. Cæsar takes no notice of coal in his description of this island; yet there is good evidence to believe that the Romans brought it into use. In the West Riding of Yorkshire are many beds of cinders, heaped up in the fields, in one of which a number of Roman coins were found some years ago.

From Horsely it appears, that there was a colliery at Benwell, about four miles west of Newcastle-upon-Tyne, supposed to have been actually worked by the Romans, and it is evident from Whitaker, that coals were used as fuel in this country by the Saxons. No mention is made of this fossil during the Danish usurpation, nor for many years after the Norman conquest.

The first charter for the licence of digging coals, was granted by king Henry III., in the year 1239; it was there denominated sea-coal; and, in 1281, Newcastle was famous for its great trade in this article, but in 1306, the use of sea-coal was prohibited in London, from its supposed tendency to corrupt the air. Shortly after this, it was the common fuel at the king's palace in London, and, in 1325, a trade was opened between France and England, in which corn was imported, and coals exported. In 1379, a duty of sixpence per ton was imposed upon ships coming from Newcastle with coals. At this period, the inhabitants of the county of Durham had obtained no privilege to load or unload coals on the south side of the Tyne; but, in 1384, Richard II., on account of his devotion to Cuthbert, the tutelary saint of Durham, granted them licence to export the produce of their mines, without paying any duties to the corporation of Newcastle. In the year 1421, it was enacted, that the keels or lighters carrying coals to the ships should measure exactly twenty chaldrons, to prevent frauds in the duties payable to the king.

Æneas Sylvius, afterwards pope Pius II., visited this island, about the middle of the 15th century, and he remarked, that the poor of Scotland received for alms pieces of stone, which they burnt in place of wood, of which at that time the country was destitute. About the beginning of the 16th century, the best coals were sold in London at the rate of 4s. 1d. per chaldron, and at Newcastle for about 2s. 6d.; and in 1553, an act was passed in Scotland to prevent the exportation of coals, which had occasioned a great dearth of fuel in that country. Queen Elizabeth, in the year 1582, obtained a lease of a great part of the mines of Durham, for ninety three years, at the annual rent of 90*l*., which occasioned an advance in the price of coals; it was afterwards assigned to Thomas Sutton, the founder of the Charter-House in London, who assigned it to the corporation of Newcastle, for the sum of 12,000*l*.; and the price of coals was immediately advanced to seven shillings and eight shillings per chaldron. Notwithstanding the several advances upon this article, when queen Elizabeth demanded the arrears of two-pence per chaldron, which had been granted to Henry V., but the payment of which had been neglected by the corporation, they petitioned for a remission of the debt on account of their inability; this was granted, and also a charter to incorporate a new company, called hostmen or coal-engrossers, for selling all coals to the shipping; in consequence of which the corporation imposed one shilling per chaldron additional upon this article. At this period the lord mayor of London complained to the lord-treasurer, Burleigh, that the free-hosts in Newcastle, to whom the grand-lease had been assigned, for the use of the town, had transferred their right to a few persons, who engrossed all the other collieries, and he requested that the collieries might be free, and that the price of coals should not exceed seven shillings per chaldron.

It appears, by an order of the hostman's company, dated A.D. 1600, that tram-waggons and waggon-ways had not then been invented, but that the coals were at that time brought down from the pits in wains, holding eight bolls each (all of them measured and marked), to the staiths by the side of the river. About this period, an engine for drawing the water out of the coal mines was invented in Scotland, by a predecessor of the first earl of Balcarras, who obtained from James VI. a patent for 21 years. This improvement was not, till some time after, adopted in the neighbourhood of Newcastle.

In a petition of grievances, presented by the house of commons to king James, in 1610, a complaint occurs of a late im-

position of one shilling per chaldron on sea-coals, rising in Blyth and Sunderland, not by virtue of any contract or grant, as on the coals of Newcastle, but under the mere pretext, assumed by the contractors, of his majesty's royal prerogative. This petition displayed so strongly the rapacity of that body of men, and the distress occasioned by it to the inhabitants of London, that the prayer of the petition was immediately complied with. It was during the same reign, that an information was exhibited in the star-chamber, by the attorney-general, against the mayor and burgeses of Newcastle, by the name of hostmen, for that they, having the pre-emption of coals for the inheritors in Northumberland, and the county of Durham, by their charter of the 42d of Elizabeth, forced ships to take bad coals, amongst which was a quantity of slate; in consequence of this they were all sued, some of them in penalties of one hundred pounds each, and committed to the Fleet prison; and the decree was ordered to be read in the open market in Newcastle, two several market days.

In 1615, there were employed in the coal trade of Newcastle 400 sail of ships, one-half of which supplied London, the remainder the other part of the kingdom; the French too are represented as trading to Newcastle at this time for coal, in fleets of 50 sail at once, serving the ports of Picardy, Normandy, Bretagne, and as far as Rochelle and Bourdeaux, while the ships of Bremen, Embden, Holland, and Zealand, were supplying the inhabitants of Flanders.

In 1612, an order was issued by the hostmen, against the secret and disorderly loading of coals, but not until they had received several precepts from the king and privy-council, concerning this abuse. They were summoned to answer again, by process from the exchequer chamber, against the governor, stewards, and some others of the company, for the above default; and as we are not informed of the result of this proceeding, we may conclude it did not terminate in their favour. Soon after this, David Ramsay, a great projector, obtained an exclusive charter to raise water from low mines and coal pits, by a method entirely original. In the year 1630, the king let to farm an impost on coals of 5s. per chaldron, for those transported out of England, Wales, and Berwick-upon-Tweed, to any part beyond the seas, except Guernsey, Jersey, and the Isle of Man; of 1s. 8d. over and above the 5s. on those to be exported, as above, by any Englishman; and also of 3s. 4d. for every chaldron to be exported except for Ireland and Scotland. In 1631, an information was again made in the star-chamber, by Heath, attorney-general, against the hostmen of Newcastle, for mixing 40,000 chaldron of coals with slates, &c.; from whence it seems, that the former fines and imprisonment had no effect, but that they had still proceeded to cheat the metropolis and the country at large, even after those severe measures of government. A. D. 1634, the king, solely by his own authority, imposed a duty of four shillings per chaldron on all sea-coal, stone-coal, or pit-coal, exported from England to foreign parts.

In 1637, one shilling per chaldron appears to have been paid, on the foreign vent of coals, to the mayor of Newcastle and corporation. Government being applied to for redress, letters were sent to the bishop of Durham, requiring him to write to the said mayor, and order an immediate restoration of the above exaction; the bishop's letter is dated 10th of January, 1638. In 1643, when the Scots besieged Newcastle, all the coal-mines were, it is said, ordered to be set on fire, which was prevented by general Leslie, who took the vessels by surprize. In 1648, coals were so excessively dear in London, that many of the poor are said to have died for want of fuel. In November 1653, articles were again ex-

hibited against the town of Newcastle, concerning the coal-trade; and the cause, as usual, was given against them. About this time the port of Sunderland appears to be rising into importance. In 1667, coals are said to have been sold in London for above 20s. a chaldron; about 320 keels were at that time employed upon the river Tyne, in the coal trade, each of which carried annually 800 chaldrons on board the ships. To adjust the difference of measures it must be noted, that 16 chaldrons of Newcastle, are equal to 31 of London pool measure, according to Mr. Eddington. In 1650, the customs upon all coals exported, were let to Mr. Martin Nowel at 20,000 pounds per annum, of which sum 19,783*l.* 14*s.* 8*d.* were for the coals of England, and 2,216*l.* 5*s.* 4*d.* for those of Scotland. Commissioners were now appointed by the lord protector, under the great seal of England, for the measuring of keels, which was performed in a new and better manner than had been before known. In December 1667, the parliament made an order, that the price of coals, till the 25th of March following, should not exceed 30s. per chaldron; and by an act made that year, after the great fire in London, a duty of one shilling per chaldron was granted to the lord mayor of that city, to enable him to rebuild the churches, and other public edifices. This, however, being insufficient, it was made three shillings, to continue twenty years. In 1677, Charles II. granted to the duke of Richmond one shilling per chaldron on coals brought to London, which was continued in the family till the year 1800, when it was purchased by government, for the annual sum of 1,900*l.* payable to the duke and his successors. This duty at present produces to government 2,500*l.* annually. At the end of the seventeenth century, 1400 ships are said to have been employed in exporting yearly from Newcastle, two hundred thousand chaldrons of coal, Newcastle measure, which was about two thirds of the whole trade. The over-sea trade in this article, at the same time, employed nine hundred thousand tons of shipping. In 1710, a duty was laid upon coals for building 50 churches; a curious and particular account of the monies collected by duties on coal, for the building of St. Paul's church, in London, from October 1, 1668, to May 5, 1716, is preserved in the *Antiquarian Repository*, vol. ii. page 40. In the year 1711, a drawback was granted on the duty on coals, used in fire-engines for working the tin and copper mines in Cornwall. Mention occurs in 1758, of a machine invented by Michael Merinzies, esq. by which coals were drawn up, not by the strength of horses or of men, but by the descent of a bucket full of water, of a weight superior to that of the coals drawn up, lifting a corve of six hundred pounds weight, out of a pit about fifty fathoms deep, in two minutes. A machine, nearly similar, was afterwards erected at Worsley, by James Brindley, on the duke of Bridgewater's canal, and is mentioned in our article CANAL. See also *bucket ENGINE*. In the year 1764, there were exported from the river Tyne, for London, and coastwise, twenty thousand chaldrons of coals, and forty thousand chaldrons of London measure for foreign parts, more than had been exported in any one year. From the years 1770 to 1776, were shipped to London, and other parts of Great Britain, 351,000 chaldrons of coals, of which 260,000 were sent to London: to the British colonies and plantations, 2,000 chaldrons; and exported to foreign parts, 5,700; in all, averaging 380,000 chaldrons, Newcastle measure, per annum. The weight of these, at 53 cwt. per chaldron, is one million, seven thousand tons; the duty paid to the crown at the ports of discharge, on 351,000 chaldrons, at 5*s.* per chaldron, is 167,000 pounds.

In 1776, from a note communicated by the surveyor of

the customs of Newcastle, we find, that 14,000 chaldrons were exported in that year from Blyth; 18,000 chaldrons from Hartley Haven; 350,803 chaldrons from Newcastle, coastwise.

The trade, thus rapidly encreasing, acquired its present importance. The following account of coals exported from the river Tyne, in the years 1802, 1803, 1804, and 1805, will give an idea of the amazing extent to which it is now carried.

	Coastwise.	Over-sea.	Plantations.
In the year 1802	494,483	41,157	2844
1803	505,137	42,808	1516
1804	579,929	48,737	3852
1805	552,827	47,213	2360

We do not here include the quantity exported from the harbours adjoining near to Newcastle, *viz.* Sunderland, which exports, annually, about three hundred thousand chaldrons; and Blyth and Hartley, which also export considerable quantities; neither do we notice the proportion consumed in the town and neighbourhood of Newcastle.

It is calculated, that the sum expended in materials for boring and sinking for coal, such as wood, iron, ropes, &c. independently of the money paid for the exclusive privilege of working, amounts, in some collieries, to upwards of 30,000 pounds per annum. By a calculation lately made, it is supposed that 64,724 people are employed by the coal trade on the rivers Tyne and Wear. See these under our article CANAL. The following is a calculation of the capital employed in the same trade.

In the collieries	-	1,030,000
In shipping	-	1,400,000
Capital employed by the London coal-merchants	-	700,000

Total 3,130,000

From this detail, the coal-trade must appear of the utmost importance, not only in a local, but in a national point of view, as a nursery of excellent seamen for the British navy; and as the means of employment for many thousands of industrious working people. Besides the important advantages already enumerated, others deserve to be noticed. Coal is in many respects, and in a very high degree, useful to the landed interest, not only by greatly enhancing the real value of those lands in which it is found, and those through which it multiplies, from the works to the place where it is shipped, but from the general improvements which it has occasioned, in consequence of the wealth it has brought into the country.

An act of parliament passed in 1803, as hereinafter mentioned, for preventing the mixing of coals of different sorts together, by the dealers, before delivery in London and its environs; and for that purpose, it required the name of the coals contained in each ship's cargo to be certified to the buyers. It were much to be wished, that some better criteria could have been adopted for ascertaining the different sorts of coals (the worth of which often are, or rather should be, rising in London at two thirds of the price of the best sorts, or less,) than merely the names of the several pits' mouths out of which they were drawn; when it is well known, that all the deeper pits are sunk through several veins of different qualities, and sometimes have one of these veins in work, and sometimes another, or perhaps several of them at the same time; whence the facility arises, of sending better or worse coals to market under the same name, according as the relative prices of good and bad coals may induce: could not the names of the different veins which have distinct qualities, have been certified, along with the coals dug therefrom, instead of the arbi-

trary, and perhaps worse than useless name of the pit, containing several veins exactly the same with, and actually opening into the works of the neighbouring pits? The following is an alphabetical list of the names of the different cargoes of coals published in the newspapers, as sold at the coal-exchange, London, during a considerable period, with the name of the river, canal, or port from which they were put on ship-board, after being conveyed thither by rail-ways, &c. (see our article CANAL) and a series of numbers, expressing the number of times that each name appeared among the coal-exchange sales of the day, during the period alluded to.

Adair's Main	-	-	Tyne	-	126
Allan's Main	-	-	Wear	-	1
Baker's Main	-	-	Tyne	-	16
Bedford Main	-	-	Wear	-	45
Bedworth	-	-	Grand Junction.	-	301
Benton	-	-	Tyne	-	4
Benwell	-	-	Tyne	-	17
Biddick Main	-	-	Wear	-	419
Bigg's Main	-	-	Tyne	-	3
Bittley Moor	-	-	Wear	-	199
Blyth	-	-	Blyth	-	14
Boundry Main	-	-	Wear	-	34
Bourn Moor Main	-	-	Wear	-	141
Brandling Main	-	-	Tyne	-	73
Byker	-	-	Tyne	-	122
Cowper Main	-	-	Blyth	-	17
St. David's	-	-	-	-	138
Eden Main	-	-	Wear	-	51
Eighton Main	-	-	Tyne	-	3
Elmore Main	-	-	Tyne	-	6
Flitworth	-	-	Tyne	-	2
Floston	-	-	-	-	2
Gate's Head Park	-	-	Tyne	-	42
Greenwich	-	-	-	-	3
Harecastle	-	-	Grand Junction.	-	232
Harraton	-	-	Wear	-	359
Hartley	-	-	Seaton Burn	-	377
Heaton Main	-	-	Tyne	-	178
Hebburn Main	-	-	Tyne	-	2
Hollywell Main	-	-	Tyne	-	2
Howard's Main	-	-	-	-	103
Hutton Seam	-	-	Wear	-	6
Kenton, East and West	-	-	Tyne	-	5
Lambton Main	-	-	Wear	-	3
Lawson's Main	-	-	-	-	266
Marley Hill	-	-	Tyne	-	12
Montague Main	-	-	Tyne	-	90
Murton Main	-	-	-	-	4
Newbottle	-	-	Wear	-	1
Newton	-	-	-	-	48
Percy Main	-	-	Tyne	-	154
Pontop, Simpson's	-	-	Tyne	-	32
----- Windfor's	-	-	Tyne	-	87
Primrose Main	-	-	Wear	-	153
Rectory Main	-	-	Tyne or Wear	-	3
Ruffel's Main	-	-	Tyne or Wear	-	105
Scotch Coal	-	-	-	-	122
Sheriff Hill	-	-	Tyne	-	8
South Moor	-	-	Tyne	-	115
Stanley	-	-	-	-	154
Tanfield Moor	-	-	Tyne	-	94
----- Pitt's	-	-	Tyne	-	25
Team	-	-	Tyne	-	4
Tyne Main	-	-	Tyne	-	101
Usworth	-	-	Tyne	-	
Wallbottle Moor	-	-	Tyne	-	

Walker	-	-	Tyne	-	292
Wall's End	-	-	Tyne	-	468
Warwick Main	-	-	Wear	-	55
Wednesbury	-	-	Grand Junction.	-	
Wentworth	-	-	Wear	-	28
Westfield	-	-	-	-	7
Wharton	-	-	Wear	-	1
Whitfield	-	-	Tyne	-	15
Willington	-	-	Tyne	-	337
Wooler	-	-	-	-	12
Wylam Moor	-	-	Tyne	-	152

The number of the different sorts of coals as above, which were in one day on sale in the market, on four particular occasions, within the above period, amounted to 24; on three market days, there were 23 different sorts sold; on three days, 22 sorts; on two days, 21 sorts; on eight days, 20 sorts; on seven days, 19 sorts; on 10 days, 18 sorts; on 18 days, 17 sorts; and on 235 market days, cargoes of from 10 to 15 different sorts of coals, were reported as sold in the London market.

From the above table, the proportionate frequency of demand and facility of supply in London, for different sorts of coals, appears to have stood as follows, viz. Wall's end, Bigg's main, Hebburn main, Heaton main, Bourn moor main, Willington, Benton, Walker, Montague main, Hartley, Blyth, Hollywell main, Pontop (Windfor's), Tanfield moor (Pitt's), Ruffel's main, Wylam moor, &c. The order of the different sorts of coals, as to price per chaldron, on ship-board in the pool, have, on several occasions, stood as follows, beginning with the highest, viz. Wall's end, Percy main, Bigg's main, Heaton main, Hebburn main, Kenton, Walker, Willington, Benton, Montague main, Adair's main, Eighton main, Cowper main, Tanfield moor, Pontop, Brandling, Blyth, Bourn main, Team, Hartley, Newbottle, Ruffel's main, Bedford main, Hollywell main, Wallbottle, &c. These prices are of course subject to vary considerably, according as the vessels arrive in considerable numbers or not, with the sorts which happen to be at that time in demand. We have been at considerable pains in collecting the above particulars, in order to throw all the light in our power upon a branch of commerce, of the first importance in a national point of view, but particularly so to the metropolis, whose prosperity and comforts so much depend upon it. In Eddington's "Essay on the Coal Trade, 1803," many highly useful particulars on this subject will be found.

By 30 C. II. ft. 1. c. 8. and 6 and 7. W. c. 10. and 11 G. II. c. 15. a penalty of 10*l.* is enacted, for defacing marks on keels, boats, waggons, &c. used for the carriage of coals in the ports of Newcastle, Sunderland, &c.; and by 15 G. III. c. 27. extended to the other parts of this kingdom. By 31 G. III. c. 36. regulations are enacted to the same purpose; and any person convicted of removing, defacing, or destroying such marks, is subject to the forfeiture of a sum not less than 40*s.* and not exceeding 5*l.* By 12 Ann. ft. 2. c. 17. every coal-bushel shall be round, with an even bottom, be 19½ inches from outside to outside, and contain one Winchester bushel; and all sea-coal and culm, chargeable with any duties by the Winchester measure, shall be charged, sold, measured, and paid by the chaldron, containing 36 such bushels heaped up. By 17 G. II. c. 35. three justices may set the retail price of coals, after landing in any place to which the 16 and 17 G. II. respecting the price of coals brought into the river Thames, doth not extend, as they shall judge reasonable. Concerning the weights, measures, and prices of coals, especially in and about London; and also concerning the duties upon them, there are various regulations enacted by about 40 different acts of parliament,

which we shall not recite. The stat. 43 G. III. c. 134, which is an "act for establishing a free market in the city of London, for the sale of coals, and for preventing frauds and impositions in the vent or delivery of all coals brought into the port of London, within certain places therein mentioned," situate within the distance of 25 miles from the Royal Exchange, in the city of London, empowers the corporation of London to purchase the coal-exchange in the said city, and regulates the mode of indemnity to those whose buildings may be requisite for the purposes of the said act. For preventing the sale of one sort of coals for another, the vender and dealer shall forfeit, for every such offence, 20*l.* per chaldron so sold; and such vender or dealer shall not be subject to any penalty inflicted by the 3 Geo. II. c. 26, on every person who shall knowingly sell one sort of coals for, and as a sort of coals which they really are not; provided always, that no ship-owner, master, or other person, having the care or command of any vessel within the said port of London, shall be subject to such penalty in respect of any number of chaldrons exceeding 25 chaldrons, for the same cargo of coals. This act directs, that no coal-meters or coal-heavers shall be unnecessarily detained on board a ship, and settles how the wages of coal-heavers shall be paid; it also requires, that ship-meters shall give certificates of the coals delivered in each lighter; and that no fractional part of five chaldrons shall be delivered into any room of a barge, under a penalty of forfeiture in the first case, of a sum not exceeding 10*l.*, and in the latter not exceeding 20*l.* This statute further enjoins and prescribes the mode of remeasuring coals by the vat; and also enacts, that in case the coals to remeasured shall not amount to the quantity mentioned in the certificate of such ship-meter as required by this act, the coal-meter, who measured them from the vessel into the craft, shall, for every bushel found deficient, if the deficiency be not equal to three bushels in five chaldrons, forfeit 5*s.* per bushel, and if such deficiency shall equal or exceed three bushels in five chaldrons, then such meter shall forfeit 5*l.* per bushel; and also the expenses of placing the vat for the remeasurement. Carmen are required to carry a bushel measure in their carts, of the form, size, and dimensions directed by the 12 Ann. c. 17; and the carmen, not having such measure, shall, for every offence, forfeit not exceeding 10*l.* nor less than 40*s.*; and the vender or dealer in such coals, shall forfeit not exceeding 20*l.* nor less than 5*l.* Carmen are also to deliver a printed ticket in a prescribed form, previous to the delivery of any coals; and in default of such delivery, for every such offence forfeit not exceeding 10*l.* nor less than 40*s.* Meters are forbidden to give certificates without actually measuring the coals comprised in them, under forfeiture of a sum not exceeding 20*l.* if it shall appear upon the remeasurement of such coals, or any part thereof, that any sack shall not contain three bushels; then the vender of, or dealer in such coals, shall for every sack of coals deficient, on the remeasurement, forfeit not exceeding 40*s.* for every sack so found deficient. Every sack used for the delivery of coals within the limits determined by this act, shall measure in the inside, at least four feet two inches in length, by two feet one inch in breadth, under a forfeiture of a sum not exceeding 40*s.*; and no sack shall, after the passing of this act, be marked at the Guildhall of London, or at the exchequer at Westminster, that shall measure less than above. The penalty on carmen for driving away coals without measuring, when required, for every such offence, is a forfeiture of a sum not exceeding 10*l.*; and the vender or dealer shall incur the same forfeiture; and such coals shall be forfeited for the benefit of the poor.

From this account of coal, as an article of commerce, and the laws relating to it, we now proceed to its natu-

ral history. There are three genera or families of coal; viz. brown coal, black coal, and unflammable coal.

I. FAMILY.—*Brown Coal.*

Sp. 1. *Common brown Coal, Bovey Coal, Surturbrand, or bituminized Wood.* Its colour is light brownish black; it occurs in mals; its longitudinal fracture is fibrous lamellar, passing into slaty or woody, and is slightly glimmering; its cross fracture is more or less conchoidal, with a shining resinous lustre; it acquires a polish by friction, and is moderately hard. Sp. gr. 1.4, when pure, but when mixed with pyrites, it is often considerably heavier.

It burns with a weak flame, like half-charred wood, giving out an unpleasant bituminous odour; when ignited in an open fire, it leaves a small quantity of white ashes. According to Mr. Hatchett (Phil. Trans. for 1804), 100 parts yield by distillation

30. Acidulous water.

10.5 Thick, brown, oily bitumen.

45. Charcoal.

14.5 Hydrogen, carburetted hydrogen, and carbonic acid.

1000

It is found in England at Bovey, near Exeter, and in smaller quantities in the island of Purbeck, some parts of Hampshire, Sussex, &c. lodged in pipe-clay. It is also found in the territory of Hesse and other parts of Germany, in Denmark, Iceland, Greenland, Italy. Faro islands, &c.

Sp. 2. *Moor Coal.* Its colour is dark blackish brown; it occurs in mals, forming thick beds, which are full of rifts and cracks. Internally, it exhibits a bright resinous lustre; its longitudinal fracture is imperfectly slaty, its cross fracture is even, approaching to flat conchoidal. It breaks into rhomboidal fragments. It is very tender, easily frangible, and of low specific gravity.

It is found in Bohemia, Transylvania, in Denmark, the Faro islands, &c.

II. FAMILY.—*Black Coal.*

Sp. 1. *Slate Coal.* Its colour is pure black, or greyish-black, and is often iridescently tarnished. It occurs in mals, and commonly possesses a high resinous lustre. Its longitudinal fracture is slaty; the cross fracture is small grained, uneven, passing into flat conchoidal. It breaks into angular fragments. It is soft and easily frangible. Sp. gr. 1.25 to 1.4. It contains from 57 to 64 per cent. of charcoal, from 33 to 43 per cent. of bitumen, and from 3 to 6 per cent. of earth and oxyd of iron. The bitumen is partly in the state of asphaltum, and partly in that of maltha; in proportion to the prevalence of the former, is the caking quality of the coal.

Almost all the common coals, as pit coal, sea-coal, caking-coal, bituminous coal, run-coal, rock coal, &c. belong to this species.

Sp. 2. *Pitch Coal, or Jet.* Its colour is velvet black. It occurs in mals, in plates, and sometimes in the shape of branches and trunks, with the true ligneous texture. It has a brilliant resinous lustre, and a conchoidal fracture. It is soft and brittle. Sp. gr. 1.3. It burns with a greenish flame and a strong bituminous odour. It occurs in Spain, the south of France, and in the Prussian amber mines, where it is called black-amber. In France, this substance is manufactured into buttons, beads, and other trinkets.

Sp. 3. *Cannel, or Candle-Coal, Splent Coal, or Parrot-Coal of Scotland.* Its colour is dark greyish black. It occurs in mals, and has a glistening resinous lustre. Its frac-

ture is conchoidal. It is much less frangible than common coal. Sp. gr. 1.23. It is very inflammable, and crackles and flies while burning. It flames much and burns quickly, does not cake, and leaves from 3 to 4 per cent. of ashes. The splent-coal of Scotland is a coarse slaty variety of the above, containing pyrites, and leaving, after combustion, about 20 per cent of ashes.

Cannel coal occurs occasionally in the Newcastle pits, in Ayrshire in Scotland, and elsewhere, but the largest beds of it, and of the purest kind, are near Wigan in Lancashire. It is an excellent fuel; it will take a good polish, and may, with care, be turned in a lathe, into snuff-boxes and other trinkets, which are often passed off for true jet.

III. FAMILY.—*Uninflammable Coal.*

Sp. 1. *Mineral Charcoal.* Its colour is greyish black. It occurs in plates and irregular pieces. It has a glimmering, silky lustre, and a fibrous fracture. It soils the fingers, is soft and friable. It is somewhat heavier than common charcoal, and burns to ashes without flaming. It generally occurs mixed with slate-coal.

Sp. 2. *Kilkenny Coal, Welsh Culm, or Stone-Coal.* Its colour is dark iron black, verging on steel-grey. It occurs in mass, has a bright metallic lustre. Its longitudinal fracture is slaty; its cross fracture is small and imperfectly conchoidal. Sp. gr. 1.5. to 1.8.

When laid on burning coals, it becomes red hot, emits a very light lambent flame, like charcoal, and is at length slowly consumed without caking, leaving behind a portion of red ashes.

The true Kilkenny coal is harder than Welsh culm, and of a brighter lustre; it often contains pyrites, and therefore gives a sulphureous odour when burning. This species of coal is found also in Hungary, Italy, and France.

These are the most considerable varieties of coal commonly known; but we must not imagine that each of them is to be met with in a pure state, in those places where they are found; on the contrary, the different qualities and proportions of their ingredients make a vast number of other varieties, fit for different purposes, according to the quality and quantity of those they contain. The various kinds of coals are often found mixed with each other under ground, and some of the finer sorts run, like veins, between those of a coarser. Mr. Magellan observed in the fine coals employed in a curious manufactory at Birmingham, that they produced a much clearer flame than he had ever seen produced from common coal, but, on inquiry, he found that these were picked out from the common coals of the country through which they ran in veins, and were easily distinguished by the manufacturers, though they did not afford sufficient indications of a specific difference. The purpose to which they were applied, was the moulding of rods of transparent and coloured glass, into shapes proper for common buttons, which the workmen performed with astonishing expedition.

On subjecting pit-coal of any kind to distillation in close vessels, it first yields watery liquor, then an ætherial or volatile oil, afterwards volatile alkali, and, lastly, a thick and greasy oil. But it is remarkable, that by rectifying this last oil, a transparent, thin, and light oil, of a straw colour, is produced, which, being exposed to the air, becomes black, like animal oils. From this and other observations, the general opinion is, that all coals, bitumens, and other oily substances found in the mineral kingdom, derive their origin from vegetables buried in the earth, during the successive processes of stratification; since it is well known, that only

organized bodies have the power of producing oily and fat substances.

Before a coal-pit is sunk, it is necessary to explore the ground by boring, but if there are already pits in the neighbourhood, sections are obtained from them, which prevent the necessity of doing so.

Boring is accomplished in the following manner: The rods are made of iron, from three to four feet long, and one inch and a half square, with a solid or male screw at one end, and a hollow one at the other, by which they are fastened together, and as the hole formed by them increases in depth, other rods are added. The chisel is about eight inches long, and two and a half broad at the extremity, which is screwed on to the end of the lower rod, and a lever or handle is put through an eye at the top of the upper rod.

The mode of operation is, to lift up the rods a little, and then let them fall, turning them at the same time gently round; by a continuance of this motion, a hole is fretted, and worn by degrees through the hardest strata or rocks. The borers can fix on handles for two, three, or four persons to work as they find it necessary. After they get down to a certain depth, the rods are wrought by a brackee; a box of wood is first inserted into the ground, to keep the rods in a vertical or straight direction, and a triangle is erected over the spot where the boring is to be made (which is about three inches in diameter), for the sake of drawing up the rods; they have one key, or temporary handle, for unscrewing, and another for securing the rods from falling back again; they use a close wimble to bring up sludge and soft matter. When the chisel is blunted, or has cut down four or six inches, the rods are lifted up, either all together, if there be convenience, or by pieces, when a key is used to keep the rods from dropping down the hole; the chisel is screwed off, and the wimble or scoop screwed on. This being put down, brings up afterwards the dust or pulverized matter of the stratum through which the chisel has cut, and shews as well what kind of matter they are boring in, as the exact depth thereof.

A considerable improvement in this essential operation was made a few years ago, by Mr. James Ryan, a gentleman of Ireland, for which he took out patents in 1805; a copy of that for England may be seen in the 2d series of the "Repository," vol. vi. p. 324; this consists in using a cylindrical cutter, something like the surgeon's trepan-instrument, by which a core, or solid and unbroken piece of each stratum, is cut, and by other tools brought vertically to the surface, in the exact position as to the cardinal points, in which it stood in the strata, and thus the quantity and direction of the dip, as well as the exact nature of the strata or measures, are correctly ascertained, the former being most essential circumstances towards determining the proper place to sink an engine shaft, for draining the bed of coals intended to be worked. The borers and apparatus of Mr. Ryan are calculated to form a hole of any size, from eight inches to near as many feet in diameter; some of two feet diameter have, we are told, been actually sunk thereby, to a considerable depth, and answer the purposes of pump and air-shafts, and that one, nearly eight feet in diameter, is now sinking thereby in Ireland! In April, 1807, Mr. Ryan presented a complete set of his apparatus to the Board of Agriculture in London, and bored a hole of some depth therewith near Kensington, under the inspection of some of its members; the cores or borings therefrom, being exhibited to the Board, and lodged with the apparatus in their repository, they voted a pecuniary reward to Mr. Ryan. From the apparent im-

importance of this discovery to mining, but to coal-finding in particular, we were induced to wish, to give an accurate description and drawings in this place of Mr. Ryan's apparatus and process, but found the time too short, after the Board of Agriculture became possessed of the same, to do it here; under the article MINING, we shall endeavour to give them in the further state of perfection, in which practice will doubtless then present the same.

Boring is of the utmost use and importance in collieries, for by boring previously to the sinking of a pit, the owner procures most essential data on which to proceed, being informed before hand of the nature of the earth, minerals, and waters through which they have to pass, and knowing, to an inch or so, how deep the coal lies, as well as the quality and thickness of the stratum bored. The boring notes of collieries are the grand arcana of the coal-mining trade, which the owners sometimes dislike to discover to the prying eyes of the philosopher. They have, however, been occasionally exhibited, which gives us an opportunity of laying before our readers an account of what relates to the boring of two of the principal collieries in the neighbourhood of Newcastle.

Section of the Strata South of the Main Dike in MONTAGUE MAIN Colliery, $\frac{3}{4}$ Miles above Newcastle.—The Numbers in the first column on the left-hand form an Index, from which it will be immediately perceived, where the same strata occur; the second column contains the number of the strata, the third the names of each, and the fourth, or numeral column, expresses the thickness of each stratum in Fathoms, Yards, Feet, and Inches.

				Thickness of each Stratum.			
Particulars of the Strata.				Fa.	Yds.	Fi.	In.
0 1	Soil	-	-	0	0	1	0
0 2	Clay	-	-	2	0	2	0
1 3	White post	-	-	0	0	2	6
0 4	Coal	-	-	0	0	0	4
2 5	Black metal stone	-	-	0	1	0	2
3 6	Grey post	-	-	1	1	2	0
4 7	Blue metal stone	-	-	2	1	1	0
3 8	Grey post	-	-	2	0	0	0
1 9	Strong white post	-	-	2	1	0	0
3 10	Grey post	-	-	0	1	1	0
5 11	White post with black metal partings	-	-	5	0	0	0
3 12	Grey post	-	-	0	0	1	4
6 13	Brown post with coal pipes	-	-	0	1	1	8
1 14	White post	-	-	2	1	0	0
7 15	Ditto mixed with whin	-	-	0	1	0	0
0 16	Coal	-	-	0	0	0	6
2 17	Black metal stone	-	-	4	1	0	0
8 18	Grey metal stone	-	-	4	2	0	0
9 19	Brown post with skanny partings	-	-	0	1	1	0
0 20	Coal	-	-	0	0	0	9
8 21	Grey metal stone	-	-	1	1	2	10
10 22	Coal	-	-	0	0	1	9
11 23	Band	} BENWELL MAIN	-	0	0	0	6
10 24	Coal		-	0	1	0	0
8 25	Grey metal stone	-	-	0	1	1	0
1 26	Strong white post	-	-	2	1	1	0
12 27	Whin	-	-	0	0	2	0
1 28	White post	-	-	1	0	2	0
0 29	Coal	-	-	0	0	1	8
2 30	Black metal stone	-	-	1	1	0	0
1 31	White post	-	-	3	0	0	0
2 32	Black metal stone	-	-	4	1	0	0
8 33	Grey ditto	-	-	5	0	2	4
13 34	Ditto post with whin girdles	-	-	2	1	0	0
1 35	Strong white post	-	-	6	0	2	0
8 36	Grey metal stone	-	-	3	0	2	0
0 37	Coal	-	-	0	0	0	8
14 38	Post girdle	-	-	0	0	2	0
8 39	Grey metal stone	-	-	1	0	1	0
15 40	COAL, BEACMONT SEAN	-	-	0	1	0	4
16 41	Strong white post	-	-	0	1	0	7
1 42	Ditto do. post	-	-	2	0	0	4
1 42	Coal	-	-	0	0	1	6
17 44	Black thill	-	-	0	0	2	4
8 45	Grey metal stone	-	-	0	0	1	2
3 46	Ditto post	-	-	0	0	2	0
8 47	Ditto metal stone	-	-	0	0	2	10
1 48	Strong white post	-	-	0	1	0	4
0 49	Coal	-	-	0	0	1	3
2 50	Black metal stone	-	-	1	0	2	4
1 51	White post	-	-	0	0	1	8
18 52	Blue metal stone with post girdles	-	-	1	0	0	0
19 53	White post with whin girdles	-	-	2	0	1	9
2 54	Black metal stone	-	-	0	0	1	5
3 55	Grey post	-	-	0	0	1	2
4 56	Blue metal stone	-	-	0	1	0	0
1 57	Strong white post	-	-	0	0	1	3
4 58	Blue metal stone	-	-	1	0	2	1
0 59	Coal	-	-	0	0	0	8
17 60	Black thill	-	-	0	1	0	4
18 61	Blue metal stone with post girdles	-	-	1	0	1	0
3 62	Grey post	-	-	0	1	0	0
1 63	Strong white post	-	-	3	1	2	6
2 64	Black metal stone	-	-	0	0	0	1
20 65	COAL, LOW MAIN	-	-	0	0	2	11
8 66	Grey metal stone	-	-	4	1	0	0
1 67	White post	-	-	2	1	0	0
21 68	Grey metal stone with post girdles	-	-	1	0	0	0
19 69	White post with whin girdles	-	-	3	0	1	6
21 70	Grey metal stone with post do.	-	-	0	1	1	0
22 71	COAL, LOW LOW MAIN	-	-	0	0	2	10
8 72	Grey metal stone	-	-	0	1	2	0
1 73	White post	-	-	0	0	2	0
8 74	Grey metal stone	-	-	0	0	1	8
2 75	Black metal do.	-	-	0	0	0	10
8 76	Grey do. do.	-	-	1	0	2	6
3 77	Ditto post	-	-	1	0	0	6
19 78	Strong white post with whin girdles	-	-	3	1	1	8
8 79	Grey metal stone	-	-	3	0	2	6
3 80	Ditto post	-	-	0	0	2	0
1 81	White post	-	-	0	1	2	0
8 82	Grey metal stone	-	-	0	0	1	0
0 83	Coal	-	-	0	0	0	6
8 84	Grey metal stone	-	-	0	0	1	0
21 85	Ditto with post girdles	-	-	3	0	2	2
0 86	Coal	-	-	0	0	0	5
8 87	Grey metal stone	-	-	0	0	0	4
3 88	Ditto post	-	-	1	0	1	6
7 89	White do. mixed with whin	-	-	2	1	0	4
8 90	Grey metal stone	-	-	0	0	1	0
0 91	Coal	-	-	0	0	0	3
2 92	Grey metal stone with post girdles	-	-	1	0	0	6
19 93	Strong white post with whin do.	-	-	0	1	2	5
				122	1	2	3

and brown. It is found in considerable thickness with but few partings, which are sandy or soft. It is sometimes in layers as thin as the common grey slate.

4th. Metal-stone; this is a tolerably hard stratum, next in point of hardness to sand-stone, solid, compact, of considerable weight, of an argillaceous substance, interspersed with nodules or balls of iron ore, and yellow or white pyrites. The surfaces of its strata are hard, polished, and smooth. When broken, it has a dull dusky appearance, is of a fine texture, like hard, dried clay mixed with particles of coal. Though hard in the mines like the sand-stone, it moulders when exposed to the action of the air. Its colour varies from black to light brown or grey; it lies in strata of various thickness.

5th. Shiver; this stratum is more frequently met with in collieries than any other; it is known to the miners under the names of black shiver, black metal, or bl-ss; the black is the most common, it is softer than metal stone, and, in the mine, is rather a tough than a hard substance. It is easily separable by the multitude of its partings. It breaks into long small pieces when struck with force, which, on examination, present the figures of small irregular rhomboids, each of which has a polished glassy surface; when broken across the grain, it exhibits a dry laminated texture, like exceedingly fine clay. It is very friable, feels to the touch like an unctuous substance, and dissolves in air or water to a fine black clay; and, like the last mentioned, it sometimes contains nodules of iron stone, often even beds of iron-stone are found in it. The colour of the shiver is not confined to black; it discovers brown, dun, and grey colours, and a variety of shades according to the proportions of each. Its strata are parted from each other by lamina of spar-coal, or other matter; as may be seen by the foregoing section.

Many of these strata are considerably thick, being frequently found from 100 to 200 feet in depth, or upwards, of nearly the same kind of matter throughout, whilst others again are of the least imaginable thickness. They are all divided or parted from each other, either by an even, smooth, polished surface, or with a very thin lamina of soft, dusty matter between them, called the parting, by which means they are easily separated; yet though the surfaces are sometimes so closely joined together, that it is with difficulty they can be separated, which is called a bad parting, they are never known to be in the slightest degree intermingled.

There are besides this principal division or parting, secondary ones also laterally, but these are not so strong or visible, and are only met with, where the texture is not of a uniform hardness or colour through the whole body of the strata. In almost every stratum there are other divisions called backs, which cross the former longitudinally, and cut the whole stratum through its two surfaces; these are again crossed by others, called cutters, running either in an oblique or perpendicular direction, and which cut the stratum through its two surfaces, and, together with the other partings, divide it into various figures. The softer kind of strata has in general more backs and cutters than the harder ones, which sometimes have thin partitions of dusty or soft matter, but like the partings are sometimes without any. Whenever the strata lie regularly they are thus divided, and generally extend in this manner through a large extent of country, though it is often otherwise, for that regularity is frequently interrupted, and the strata disordered by various chafms, breaks, or fissures, which are called

dikes, hitches, and troubles, according to their dimensions, and the matters with which they are filled; first,

Dikes, or faults, are fissures of the largest kind, which seem to be cracks, or breaks, of the solid strata, occasioned by one part of them being broken away and fallen from the other. They generally run in a straight line for a considerable length, and penetrate from the surface to the greatest depth ever yet tried, in a direction sometimes perpendicular, and sometimes oblique, to the horizon, in which case they are said to hade or underlay. The same kind of strata are found lying upon each other in the same order, but the whole of them are sometimes greatly elevated or depressed on the one side of the dike or on the other. These fissures are frequently two or three feet wide, and at other times many fathoms. If the fissure or dike be of any considerable width, it is generally filled with heterogeneous matter, different from that of the solid strata on each side of it; sometimes with clay, gravel, or sand, sometimes with a confused mass of different kinds of stone lying edge-ways, and at others with a solid body of free-stone or even whin-stone. When the fissure is of no great width, suppose two or three feet, it is then usually filled with a confused mixture of the different matters which compose the adjoining strata, consolidated into one mass. If the dike runs or stretches north and south, and the same kind of strata are found on the east side of the dike, in a situation with respect to the horizon, 10 or 20 fathoms lower on the other side, it is then said to be a dip dike, or down-cast dike, of 10 or 20 fathoms to the eastward; or counting from the east side, it is then said to be a rise dike or upcast, of so many fathoms westward. If the strata on one side are not much higher or lower with respect to the horizontal line, than those on the other, but only broken off, or removed to a certain distance, it is then said to be a dike of so many fathoms deep, and from the matter contained between the two sides, it is denominated a clay, a stone dike, &c. There are some, though they are not often met with in the coal countries, whose cavities are filled with spar, ores of iron, lead, or other metallic or mineral matters; and it is pretty well known, that all metallic veins are nothing else than what in the coal countries are called dikes. It generally happens, that to a considerable distance on each side of the dike, all the strata are in a kind of shattered condition, very tender, easily pervious to water, and debased greatly in their quality, and in their inclination to the horizon often altered.

2dly. A *hitch* is only a dike of smaller degree, by which the strata on one side are not elevated or separated from those on the other more than a fathom. These hitches are denominated in the same manner as dikes, according to the number of feet which they elevate or depress the strata.

3dly. *Troubles* or bends may be called dikes of the smallest degree, for they are not a real breach, but only a tendency towards it. The strata are generally altered by a trouble or bend from their regular direction to a different one. When the regular course of the strata is nearly level, a trouble will cause a considerable ascent or descent; where they have, in their regular situation, a certain degree of ascent and descent, a trouble either increases or alters it to a contrary direction; and a trouble has these effects upon the adjoining strata in common with dikes, that it greatly debases them from their original qualities; the partings are separated; the backs and cutters disjoined, and their regularity disordered; the original cubic and prismatic figures, of which the strata are composed, are broken, the dislocation filled with heterogeneous matter, and the whole strata are reduced to a softer and more friable state.

Notwithstanding that the dikes and hitches, or faults, as they are as generally called, are filled with extraneous matters, in a considerable degree of disorder, yet there generally is a *leading*, as the miners call it, or streak of imperfect and mixed coal, which leads or directs to the vein on the other side of the fault, whether the same be higher or lower, and by which they are in a considerable degree directed, in cutting the fault to recover their vein; in very considerable faults, like that on the north of Newcastle, which drops the strata 540 feet, it is not probable that any leading can be traced. In the coal-mines near Bath, there is a fault which has altered the level of the same vein of coals, much more than in the above case.

By the sinking of the shaft, which is a narrow, perpendicular passage, a communication is opened with the various strata above-mentioned, and the different veins of coal. The strata of this fossil are seldom or never found to lie in a true horizontal situation, but generally have an inclination or descent, called, as before noticed, the *dip*, to some particular part of the horizon. If this inclination be to the east, it is called the east dip and a west rise, and according to the point of the compass, to which the dip lies, is it denominated. This inclination, or dip of the strata, is found every where; in some places it varies very little from the level, in others very considerably, even so much as to be nearly in a perpendicular direction; but whatever degree of inclination the strata have to the horizon, if not interrupted by dikes, hitches, or troubles, they are always found to lie in the regular manner first mentioned. They generally continue upon one uniform dip, until they are broken or disordered by any of the above interruptions. Wallis, in his "History of Northumberland," tells us, that the strata in that part of the island generally rise to the north-west and dip to the south-east. Dr. Stukely, in his "Itin. Curios." 1725, says, that some of the coal-works in the same country dip full east; but it is plain, he adds, that south-east is the natural dip. As those at Whitehaven, inclining south-west, receive, he supposes, a counter-bias, as being on the west side of the island; he further observes, that the principal dip is to the south-east; yet in this country dips in various directions, as the fall of valleys, or beds of rivers, as well as the causes above-mentioned, occasionally influence its primary bent. See *Geology*, Plate I. fig. 1. where *aa* is intended to represent the vegetable mould or alluvial matters deposited on the surface of the regular strata, represented by *b, c, d, e, &c.* on the left-hand side of the figure. *AA*, and *BB*, are intended to show the dikes, by which the same are disjointed, depressed, or elevated, as before described; and where *CC* shows a hitch or smaller dike; *DD, EE, FF, and GG*, are the representations of troubles or bends of the strata.

Such are the usual dispositions of the strata; two principal difficulties are met with in the descent, the first is in keeping out quick-sands where they occur, and the second to keep the shaft so dry as to allow the men to work. A quick-sand is kept out by a process called "tubbing," that is forming a circle in the inside of the pit where the sand bed is, with staves of oak, each piece being shod with a sharp piece of iron; these are driven through the stratum of sand, so closely joined that no water can penetrate, and are kept in their situation by internal hoops or kirbs at certain distances; the water is drawn out now generally by a steam-engine and pump. See *STEAM ENGINE, PUMP, Pressure ENGINE, Bucket ENGINE*.

Through a large district of South Wales, their highly valuable veins of coals, of which an account was lately presented by Mr. Edward Martin to the Royal Society (and published in the *Philosophical Transactions* for 1806, p.

342, &c.) are gained at comparatively trifling expences, compared with most of the Newcastle pits; the depth of the valleys and heights of the hills in that part of the country, allowing several successive and thick veins of coals to be worked by tunnels into the hill above the level of the rivers, or springs of water, in the valleys; and the coals, and the valuable iron ore which also abounds, are let down into the boats on the canal tunnels, or as loading for tram-waggons in the tunnels below; through which they are conveyed to open day, and thence to the iron-works or place of shipping; of several of these curious works in South Wales we have given concise accounts, under the names of the particular canals, railways, &c. in our article *CANAL*; and we shall take occasion, as the names of them occur in our work, to give several material additions and corrections which have come to our knowledge, principally through the kindness of Mr. Martin above mentioned, since that article was put to press, so as to render the same, we hope, quite complete.

In the environs of Glasgow there are considerable coal-mines of excellent quality, which are also worked at an easy expence; they are found under beds of quartzose freestone, which in some mines are more than 140 feet thick; it adheres to the freestone, without any intermedium. The coal appears at the depth of 30 feet from the surface, in scattered lines running in an irregular manner through the midst of the freestone; then follow beds of the same stone without the least vestige of coal, but as the beds descend, the coal reappears in small straggling and interrupted seams from three to four inches thick; these are again succeeded by an unmixed mass of freestone, which falls through a depth of more than 40 feet, and terminates in solid and continued beds of coal. It is much to be regretted that the operation of boring is held in so little estimation in Scotland, but the reason is very obvious; in England it is made a distinct trade, and is conducted by men of information, who have been regularly brought up to the business: in Scotland it is effected by any common workmen about the pits, possessing neither information nor experience, and their accounts are consequently so confused, imperfect, and equivocal, as to merit no confidence whatever.

The great and universally felt importance of its veins of coals to this country, makes us again regret our inability, at present, to lay before our readers, any more than a few of the principles, of the modern and yet unpublished discoveries of Mr. William Smith, on this and other subjects connected with the stratification of the British islands (see our articles *Structure of the EARTH* and *STRATIFICATION*.) It is confessedly of the first importance, either to the inhabitants of a district in general, or to the owners of the soil in particular, to be able to detect and work such veins of coal, as may exist under their soil; and hence we find on inquiry in the neighbourhood, that almost every common, moor, heath, or piece of bad land, in parts where coals are scarce, have at one time or other been reported by ignorant coal-finders to contain coal: how many times, for instance, have our grandmothers and nurses, repeating their stories, told us, that plenty of coals might be dug at Blackheath, near Woolwich, and on other commons near London, if government had not prohibited their being dug, for encouraging the nursery of seamen, &c. Our inquiries, and those of Mr. Smith, have brought to light hundreds of instances, where borings and sinkings for coals have been undertaken in such situations, and on such advice, in the southern and eastern parts of England, attended with heavy, and sometimes almost ruinous, expences to the parties, though a source of profit to the pretended coal finders, who, or some of their never-failing race of successors, equally sapient, have in many instances been able to return to the same spot

or neighbourhood, and persuade a new proprietor to act again the same farce, and squander his money on an unattainable object; for such, we can without hesitation pronounce, the publication of Mr. Smith's map and sections of England will prove it to be. This gentleman, more than 15 years ago ascertained, by an actual examination of the country, that the stratum on which London stands, is the highest but one (the Bagshot-Heath Sand) in the British series of strata, and that whether we proceed from London directly for the Newcastle coal mines, in a direction not greatly to the west of a north point, or to those in Somersetshire, near Bath, lying in an easterly direction, or rather south of it, from the metropolis; or whether we travel thence to the nearest coal mine, lying in any intermediate direction, as in the counties of Durham, Yorkshire, Nottinghamshire, Leicestershire, Warwickshire, Gloucestershire, &c.; on a careful examination we shall find, the very same succession of strata occurring upon the surface, and may easily satisfy ourselves, by an examination of the quarries, pits, and even of the hollow roads and ditches, which are every where to be found, of the identity in the nature of the various stratified matters, as sand, chalk, marl, clay, limestone, &c.; and of the exact occurrence of each in the same order, as we proceed outwards from the metropolis. A more particular examination will next satisfy us, that these appearances are occasioned by the several strata which we have mentioned, successively rising towards the north west, (and consequently dipping in the contrary direction) generally speaking, and ending one after another, with very curiously indented or fingered edges, after which the same stratum never occurs again: the chalk strata, for instance, will be quitted near Dunstable, in the road to Warwickshire, and never be seen afterwards on the surface, or be found sunk to in any pit or excavation during all the remainder of the journey, or even in pursuing one in the same direction, to the utmost limits of the British islands; and, though we shall, in such an examination, meet with a number of different sands, clays, and other strata, which may seem at first sight to be recurrences of the same stratum, after it has risen to the surface and ended; yet, on examining two of such more minutely, we shall find, either the strata lying in undisturbed contact with them above and below, to be different in the two cases, or their visible or chemical qualities to differ, their thicknesses to vary, or, that the same particular species of organic remains are not found imbedded, or their impressions left in one of the strata, as are observable in the other: wherever, on the contrary, these circumstances concur, they may be said to prove the identity of any stratum, at however distant points it may be compared; and for shortening our inquiries for such purpose, science happily presents us with the prospect of similar advantages, to those possessed by the botanist of the present day; who, instead of examining all the parts of a plant supposed to belong to particular genera or species, proceeds at once to examine some one or two of them, which the writings of former botanists have shown to be essential characters of that particular plant; and it is no unreasonable hope now to form, that the essential characters of each of the most remarkable and useful strata in the British series, will ere long be generally known to mineralogists, since they have become so to some particular individuals. Each particular stratum appears to us, to have formed part of one vast plane, with a slight inclination towards the south-east, or nearly, and with great extension in the directions of N. E. and S. W. in these latitudes; prior to the truly enormous violence with which the earth has since been dislocated and broken, during the formation of the dikes, faults, hitches, and troubles, which we have had occasion more particularly to mention in this article, and some greater ones, which we shall have future op-

portunities of mentioning, particularly that by which the whole of the land of England, south of the river Thames, has been disturbed and broken from its original position (dipping S. E.) into one, in which all the strata north of a line passing not far from Hastings, Battle, East Grinstead, Guildford, &c. have now a much greater dip, nearly at right angles thereto, or N. E.; while, on the other, or south side, they have just a contrary or S. W. dip; but with as many local deviations or partial dips in each case, as are usually to be found, and which sometimes vary, perhaps in several directions, many times in travelling a mile, and yet on the whole, the strata keep rising as above, the planes being the longest in one particular direction.

The organic remains, or exuvia of different animals, and the remains of plants, are found lodged in our strata in the greatest abundance, and, to superficial observers, appear to have no method or arrangement therein; but, on a closer examination, and taking care to notice the minuter differences in these organized remains, it will be found, that each particular kind, either alone, or mixed with one or more distinct kinds, occupies a certain thickness of strata, sometimes but an inch, or less, and sometimes many feet, but extending to the greatest distances in the plane of that stratum, and that either above or below those limits, the remains will be found to be different, or none are found; hence the layers of shells, plants, &c. become the most useful, as well as certain, criteria of the identity of strata; these often changing, where the obvious qualities of the strata appear unchanged, by which means they divide thick strata into thinner ones, and furnish us with so many more ascertained or known points in the progression of strata; which, in the confined operation of sinking a shaft or well, is of the greatest importance, but particularly so in boring, for ascertaining the strata. See *Philosophical Magazine*, vol. xxv. p. 45.

We have been led to enter thus far into Mr. Smith's theory of the stratification, in order to explain in this place some part of that which relates more particularly to the finding of coal; and as the mention of organic remains has, and must often again occur, we beg here to call the attention of our readers to three distinct eras observable, relating to fossil organized bodies; 1st, that period in which the animals themselves, or their exuvia, and vegetables, were quietly deposited and buried, in and among the successive depositions of strata, taking effect according to laws, apparently as uniform and extensive as those of crystallization; 2d, a period wherein the strata were ruptured, torn, and washed by mighty currents of water, and during which great quantities of the organized remains from within the strata were detached, broken, and worn, and at length left with the gravel and alluvial matters, which now cover almost every part of the surface, although, in many places, such alluvium is no thicker than what is called the vegetable mould; 3d, a period extending from the last to the present time, in which the waves of the sea on its coasts, the currents of inundated rivers, and the other operations of nature, have, though in a very limited degree, been continuing the same process of washing out, breaking, exposing, and wearing the original organized matters of the strata, those which had in the second period been deposited with the gravel and alluvium; and exposing also, in many instances, organized remains belonging to an earlier part of the present or third period; which is further distinguished, by the growth of immense beds of vegetable, or peaty matters on the surface, which have inclosed the remains of recent animals, vegetables, &c. mixed with the occasional depositions of muddy waters, to which such have, in low situations, been repeatedly subject.

When, therefore, we speak of organized remains, without

further explanation, we wish to be understood as meaning those of the strata, of the first era, no otherwise altered than by the gravity or chemical action of the surrounding matters; when we wish to speak of the organized remains peculiar to the strata, but disturbed during the second era, we shall, as Mr. Smith does, call them *gravel fossils*; and this, whether they bear marks of breaking and wear, or not, if they are found deposited with gravel, or among angular or worn fragments of matter near the surface, the evident effects of collision and attrition; when we have to mention the organized fossil matters of the third era, if they appear such as have been deposited by water among gravel, and the depositions of water, as above mentioned, or have been buried by the labour and works of men or animals, and undergone a mineralization, we shall call such *recent fossils*, while those which owe their burial, and probably their change and preservation, to vegetation, shall be called *peat fossils*; these terms and distinctions appear to us essentially necessary for avoiding, in these inquiries, endless mistakes and absurdities, into which former writers on this subject have been led, for want of such discriminations. When organized matters of the present race, are found on or near the surface of the earth unchanged, at least, not mineralized, they will still be denominated recent shells, bones, teeth, horns, plants, &c. and will be sufficiently distinguished from our recent fossils above.

A careful examination of the several strata which intervene and end, between London and any of the nearest points mentioned as coal-districts, will show these strata to be very various in their qualities, and in their thicknesses (altogether amounting to several hundred fathoms), with no one circumstance so observable among them, as the total absence of distinct vegetable impressions or remains (among their numerous animal remains,) except of wood, and which, it is observable, are generally, we believe we might have said always, found in these upper strata in the series, in casual, detached, and broken pieces of the trunk, almost like chips and billets, and generally with the appearance upon them of previous rottenness and wear, from tossing or floating in water; not unfrequently also, this supposition is strengthened by the worm-holes with which these detached pieces of wood abound, particularly in the Woburn Sand stratum, where mineralized remains of the worms or animals which perforated the wood, found below the fuller's-earth stratum, are still seen occupying the holes in the silicious wood, of which we have specimens now before us. The pieces of wood found in the series above the coal, are in slates as various as the matters of the strata inclosing them; in many instances they are silicious, pyritic, or ochreous, less frequently, perhaps, they occur in a soft rotten slate, sometimes like charcoal, and at others bituminized almost to the consistence of pitch; and these last specimens they are, which, when accidentally accumulated, as at Bovey-Tracey, and many other places, on the out-crop of the Purbeck pipe-clay stratum, have been improperly denominated coal strata; and in Sussex, and other parts, have misled the coal-finders, or perhaps rather their credulous employers, above alluded to.

This absence of vegetable impressions will be found to continue in our journey outwards from the metropolis, until a remarkable stratum is passed, called by the miners in Somersetshire the "red earth," being a very red ferruginous earth, or stone, something like that on which the city of Coventry stands: from hence, examining westward or northward, we shall find a material change take place, in the animal remains becoming very scarce, and vegetable impressions beginning to appear and increase, among a certain series of strata, called, by the miners of several counties, the "coal measures," which are often remarkable for their quick and

varied alternations, as the two sections of coal strata or measures, which we have given in this article, will exemplify. For many fathoms together, among some of the coal measures, particularly in the argillaceous or coal-shales, scarcely a lamina of the strata, as thick as paper, can be split off, without exposing the impression or bituminized remains of some plant, as mentioned hereafter, many of them highly beautiful: as those appearances increase, veins of coals, or uniform strata of these bituminized vegetables, without the intervention of shale, or earthy matters, occur; these are often extremely thin, and have intervening strata, or coal measures, sometimes of considerable thickness between them, so that in some of our British coal-pits, 30 or more distinct and separate veins of coal are sunk through, before the "main," or most desirable seam of coals is reached; from which, if the pit was to be farther sunk, or if we travel westward or northward to the ending of the several measures sunk through, and over those below, we shall at length find these coal-measures end, and what the miners call "dead earth," or strata, as dissimilar to coal-measures as those at the top of the British series, already mentioned, will be found to succeed through a certain series of strata, but then other coal-measures will be found to occur again, &c. These different sets of coal measures traversing the country, as now seen on Mr. Smith's map, have often been noticed by practical men, and by some writers, under the title of "runs of coal;" and that on which Newcastle is situated, probably from its early and great importance in supplying the metropolis, has been called the "great run." The first workings of all our coal has evidently been upon their out-crop, or breaking to day, either at the ending of the strata, or where the former and convulsive heavings of the strata have left their edges bare, or nearly so: but experience has progressively proved, as the improvements of pumps, and machinery permitted, that the coals were better in quality, and less troubled, the farther they were pursued into the deep, or in the direction of the "ten o'clock run," from their out-crop, most generally: and thus the Newcastle mines have been progressively creeping nearer to the sea, and now extend to, or under it, and still find their coals improve; of which the Wall's End coals, brought to the London market, are an instance: in like manner, the mines on the opposite coast, near Whithaven, for working seams, which the local dip of that part occasions to descend under the sea, have their works now extended near a mile under the ocean, at about six hundred feet beneath its bottom. Accordingly it has occurred, that mines have been begun higher and higher up, on the series of strata, called coal-measures, and, consequently, had their pits of greater depths, and now the attempt is making at Bath-Easton, in Somersetshire, of sinking in matters above the red earth, in hopes of there reaching the Somersetshire coal-veins, hitherto not worked so far eastward, or into the deep, by some miles, although some of their mines, owing to the rapidity of the partial dips are, we believe, working at the greatest depths of any in the kingdom. An application of the principles above explained will enable any ingenious person to judge, whether his district is likely to contain coals, at practicable mining depths; for it seems an useless inquiry, whether they exist or not beyond this; for instance, whether the vicinity of London, and the more southerly parts of our island have the coal veins of the middle counties dipping under them, it can be of small use to inquire; from the immense number and thickness of the known strata which intervene, and contain no coals, or other very valuable matters. The very open and porous slate of some of these strata, the chalks (more than 50 fathoms thick) for instance, occasion them to be so powerfully supplied with

water, as to render the prospect of sinking even one shaft through them at London, utterly hopeless. Mr. Dodd, whose scheme for a tunnel in chalk under the Thames, at Gravesend, we have noticed in our article CANAL, has since complained to the public, that the boring of one small augre hole, before his shaft was sunk, let up so much water into it, that he was unable to penetrate more than 122 feet deep; what then was he to have expected, had he ever come to open the length of 900 yards of an 18 feet tunnel in this same chalk? We hope to be excused for these digressions, as they tend, we think, to illustrate the question, of the practicability of finding coals, through a large and important part of our island; and we shall now proceed to the methods used in sinking for coals.

The first operation after sinking the engine pit of a coal mine is the working or driving in the coal, and sinking the first coal pit; the situation of which should be a little higher up the plane of the strata, or to the rise of the engine pit, that the water which collects may not obstruct the working of the coals when the engine stops: yet it should not exceed the distance of 30 or 40 yards, because when the first mine is to be driven a long way, it becomes both difficult and expensive. After the pit is thus sunk to the coal, the miner is to begin his work; he first digs or undermines with his pick-axe, a light instrument for hewing coal, (nearly in the shape of an instrument of the same name used by paviors and gardeners) at the bottom, and on one side, into the seam or stratum as far as he can; he then forces down great pieces of coal by a wedge and mallet, taking care to leave, at proper intervals, pillars for supporting the roof.

Fig. 2. in Plate I. represents the plan of the workings of a coal mine, where A A represents the main passage or gangway, in the direction of the dip, and in which tram-plates or rails are now often laid, for the passage of the trams loaded with coal to the pit or winding shaft; B B, C C, D D, and E E, represent other parallel and straight passages, between the pillars of coal, *a, b, c, d, &c. e, f, g, b, &c.* which are left for supporting the roof and strata above.

The coal is often wrought in this manner to the limits of the mine; when these pillars, or so many of them as can be got, are taken out by a second working, and the roof and other solid strata are permitted to fall down and fill up the excavation, often to the great and permanent injury of the surface of the land, and sometimes to canals, and other works, as particularly mentioned under our article CANAL.

If the roof and pavement are both strong, as well as the coal, and the pit only 30 fathoms deep, then two-thirds or three-fourths may be taken away at the first working, and one-third or one-fourth left in pillars; if tender, it will require a larger proportion to be left, probably one-third or nearly one-half.

There is an overman, whose office it is to go through the pit to examine the places which the men have wrought, to measure their work, and to see that the pit is free from inflammable vapour. There is also a deputy overman to superintend the pillars of coal that are left, and to set up props or build walls, when the roof is loose and threatens to fall. The business of the person called an "onsetter" is to hang the corves (usually baskets made of hazel rods) upon the rope to be drawn up the shaft. Collieries are liable to an accident of a very dangerous nature, called a "creep" or "fit," when the pillars of coal are left so small as to fail or yield under the weight of the superior strata, or when the pavement of the coal is so soft as to permit the pillars to sink into it, which sometimes happens, by the great weight that lies upon them; in either case the solid stratum above the coal falls and

crushes the pillars to pieces, and closes up a great extent of the working, or probably the whole colliery.

Mr. Ryan, we understand, proposes to cure the defect of a soft pavement, in the principal passages, which are required to stand for a long time, by forming them in the coal, of the form shown in *fig. 3. Plate I.*, or nearly approaching to elliptical; the tram-plates or rails *a, a*, in their bottoms occupying nearly the whole width in that part, with the undisturbed coal nearly or quite meeting under them: in this case it will be necessary to construct two parallel passages at a proper distance, one for the going of the trams to the pit, and the other for their return. Another fatal accident to which coal-miners are subject, in the vicinity of old workings between water-tight strata, arises from the water contained in these artificial cavities, or sometimes in natural cavities or fissures filled with loose and porous matters, bursting in and suddenly filling their works: the only security against this, is to bore an augre hole before the working as it proceeds, to prove the regular continuance of the coal. The collieries about Radstock, on the Somersetshire coal canal, have been subject to this accident, on imprudently cutting through their faults, or dikes, which, as well as several of their intervening strata, are of water-tight matters.

There are two other evils to which coal mines are subject; hydrogen gas called by the workmen, "fire-damp" by the explosion of which many lives are lost; and carbonic acid gas commonly called "choak damp," which is not so fatal as the former. Hydrogen gas is principally generated, by the contact of pyrites with water in some of the old workings of the collieries which have been neglected and not sufficiently ventilated: it there accumulates until discovered by the occasional visit of some of the overmen, whose office it is to examine the old workings called "wastes:" sometimes for want of due caution it causes the death of many of the miners, being set on fire with their lights. On these occasions the men throw themselves on their faces to the ground to avoid the return of the blast, as there is more danger to be apprehended from the vacuum formed by the total consumption of the inflammable gas, than from the effect which the fire has upon them. It rarely happens after an explosion that the men are much burnt; they suffer more by the violent concussion of atmospheric air, rushing into the workings to fill up the vacuum, than from any other cause. After an accident of this kind, it is generally considered dangerous to enter the pit for some days, on which account it is to be feared many lives are lost which might have been saved by immediate assistance. At Whitehaven and Workington, where the inflammable gas is very prevalent, the miners often work without candles, in driving their adits for ventilation, by the light of a flint mill, or of sparks produced somewhat in the manner of a razor grinder's wheel: but the only effectual method of preventing accidents of this nature, is to pay due attention to the state of the old workings, and to cause a thorough ventilation by the methods usually adopted, which are the following: the air is put in motion by means of a large furnace placed near the edge of one of the shafts inclosed in a covered building from which is a tube descending into the pit. The heated air, thus ascending through the chimney, is succeeded by cold from the shaft, which in its turn is replaced from the lowest part of the mine. The whole is thus successively removed, and its place is supplied by air which finds its way from above, through another communicating shaft open to the day. The certainty of this operation has evidently no dependence on the depth of the mine, its extent, or its form. The brisk current thus produced below, naturally takes the most direct course betwixt the two shafts. The ventilation on each side is therefore accomplished, by

means of a continued communication formed betwixt the two shafts in any required direction, by opening the proper avenues, and closing all others. A continued current is sometimes made to pass in this manner for twelve or eighteen miles, see *fig. 4. Plate I.* where *S* represents the shaft, and *A* the adit or working of a mine which is subject to damp or foul air; *a a a* is a close pipe, leading from the part most affected to the surface of the ground, and there entering the lower part of a furnace, *F*, and ascending through the fire therein, by the heat of which a current of air is constantly thrown out of the upper end of the pipe: this method is applicable, and very necessary, where particular and distant parts of the mine require ventilation; because by this means fresh air can be made to descend down the same shaft, and along the adit through which the pipe and furnace cause the foul air to ascend; for the more general ventilation of coal-mines, and where fresh air can be supplied by other shafts, as it generally can in mines at work, by means of the winding shaft, the water-shaft or engine pit, or both, a simpler mode is adopted, as at *Worsley mine*, on the *duke of Bridgewater's canal*, and other places, shown in *fig. 5.* where *S* represents the air or ventilation shaft, having a common roll and winch-handle erected over it, from which a cage or iron basket, *c*, is suspended by a chain, and in which a large fire of coals is constantly kept burning, some yards below the surface of the ground; the winch-handle is made use of for drawing the fire to the surface as often as the same wants replenishing.

Choak damp is rarely attended with any ill effects, and is easily discovered by its extinguishing a candle. The safest method of exploring collieries subject to this evil, is to walk as erect as the workings will allow; for choak damp being heavier than atmospheric air, occupies, of course, the lower part of the mine. It is more difficult to exhaust this gas by ventilation than fire damp, as the latter ascends, from its being lighter than atmospheric air, whilst the other, by its gravity, is forced upwards with great difficulty.

It is not exactly determined by what means choak damp is generated in coal mines, but it is generally supposed to proceed from the putrefaction of vegetable substances.

After the operation of "hewing," or digging, is performed, the coals are brought to the bottom of the pit, in corves or baskets, either drawn along the ground in the manner of a sled, or upon a small rail or train road as they are called in *Shropshire*, hooked on to a chain, and drawn or wound up by a rope to the surface. This is often effected by a machine called a *gin*, wrought by horses. Of these winding machines there are various kinds; some wrought by water, others by the fire engine; several of the last named, are only convenient in some particular situations; that wrought by horses is therefore in most general use. There are, besides, a sort of gins called "*whim gins*," and another known by the name of "*macaroni gins*." In the *whim gin* the ropes run upon two wheel-pullies over the shaft, the roller is at some distance, and the circular track of the horses is not round the shaft. See our article *MINE WINDING Engine, and Apparatus*. To receive the coals, there are two "*bankmen*," who take off the corves at the top of the pit, and empty, or, as the workmen call it, "*teem*" them. The coals, by teeming, are discharged into waggons, by means of a grated spout which allows the small coals to go through it, whilst the large pass into the waggon. Boys or women attend to throw aside the pyrites, or, as they are technically called, "*brasses*," or in other places, "*slates*," which are sold to the copperas manufacturers. See *COPPERAS*.

The coal-waggon has been already shortly described un-

der our article *CANAL*; and for a fuller account, we refer to *WAGGON*. Our account of the waggon-ways, and rail-ways, also occurs under the article *CANAL*; and for other particulars relating to the conveyance of coals from the mines to the wharfs and vessels: See *WAGGON, RAILWAY, and STEATH*.

Having thus given a description of coal-mines, we shall give an account of a visitation to a pit. That in which the best view is gained, and which can be entered with the greatest ease and safety, is in the vicinity of *Newcastle*, viz. *East Kenton colliery*, the property of *Messrs. Knowsley and Chapman*. Having previously obtained permission of a viewer, or some other person concerned in the colliery, a small hand lantern must be provided, a light being necessary for each person. It is also advisable to take a change of dress, at least of upper cloaths; strong boots to keep the feet dry, and an old hat. Being thus prepared, proceed to the *leath*, which is by the river side, about four miles above *Newcastle*, a pleasant excursion by water. When there, some of the men, who have been apprized of your coming, will assist in seating you on a set of small empty coal waggons, capable of containing two persons each, seven of which are drawn along a rail-way by one horse. As soon as you are placed, with your candles lighted, you set off at full speed, with a boy in the first waggon, for a charioteer, into a tunnel, or subterraneous passage six feet high, about the same breadth, and three miles in length. It is particularly necessary to guard against putting your hands suddenly out of the waggon, as the tunnel, in most places, is only wide enough to admit the waggon and horses, and you are of course by doing so in danger of receiving an injury; but by sitting quietly, you ascend very smoothly, till you arrive at the place where the men are at work. At your first entrance into the tunnel you are struck with the noise of the waggons, which, being fastened with chains to each other, and going sometimes at the rate of ten miles an hour, make a sound resembling thunder. The passage is in general hewn out of solid rock, composed of metal stone, a sort of schistus. Where there is not rock, it is arched with brick or stone. The water from the pit runs down by the side of the rail-way to the river *Tyne*.

At intervals there are double rail-ways; and where you come to one of these your driver stops his horse, and a dead silence ensues; he then calls aloud, and listens to hear if any loaded waggons are coming down, that they may there pass each other; when he is past, your driver renews his speed, until he reaches the next interval, when he repeats his call, and should no answer be heard in return, he proceeds. If, by the negligence of the boys, the waggons should meet where there is no double rail-way, the boy with the empty waggon unlooses his horse, which is taught to turn round, and force the waggons back with its breast, until they reach the double part, where they can pass each other.

On the sides of the tunnel you will observe several fungi of a pure white, which, by the heat of your hand, or exposure to the open atmosphere, dissolve into water. The air up the tunnel is cold, but perfectly pure, but as you approach the workings a considerable degree of warmth is felt. You alight from your waggons in order to view the different operations to which your guide will conduct you.

In the upper seam or stratum, the coal is not much wrought on account of its inferior quality. Here you will see the stables for the horses, the steam-engine for raising the coals from the lower seam, and the ventilating furnace, by which the impure vapours are drawn off. Here you will also be shown, on the roof of one of the lateral openings of

this level, a variety of curious specimens of plants, somewhat like grasses, ferns, vetches, &c. impressed upon a sort of blue slaty stone; the different plants are remarkably distinct from each other. There is also in one part the trunk of a tree, many blocks of which have been taken out to make seats in a neighbouring garden; as far as the stone has been cut, the tree has been traced even to its smallest branches, and the roughness of the bark is still preserved in the stone: the whole of this stratum is one uninterrupted continuation of these impressions of vegetables: it is nearly horizontal, and is 112 yards from the surface.

In East Kenton colliery, there are three shafts or perpendicular openings, for raising the coals. The first is the pit at the day, near the village of Kenton: it is circular, 56 fathoms deep, and at present only used for delivering coals for sale at Newcastle. The coals are drawn up in baskets. The bottom of this pit is on a line with the rail-way from the river. The second shaft is eighteen and a half fathoms deep, and at a short distance from the bottom of the first. It is square, and just admits the waggons, which are drawn up and let down by the steam-engine. The third shaft is only 7 fathoms deep. After having examined the works, you may be drawn up to the surface by the first shaft in a basket in about two minutes, in which space of time you will have ascended 56 fathoms. But should this mode of conveyance not be approved of, you may return again by the tunnel. Brand's History of Newcastle. Com. Magazine. Dr. Black's Lectures. Wallace's Northumberland. Pennant's Tour. St. Fond's Travels. Picture of Newcastle. Papers of the Literary and Philosophical Society of Newcastle upon-Tyne. Philosophical Transactions.

COAL-balls, balls made of coal and clay, or slack, for firing. These balls are made with $\frac{1}{4}$ of clay, without sand or gravel, and $\frac{3}{4}$ of coal-dust, or *culm*, well mixed, and formed either into round balls or into bricks. This coal-dust being the refuse of the mine, makes this sort of firing cheap. See Phil. Trans. N° 460 sect. 3. See **PATENT COAL**.

COAL bushel. The measure directed to be used in London and other places for retailing coals, is different from the Winchester bushel for corn, or malt bushel, 18 $\frac{1}{2}$ inches wide, and 8 inches deep, containing 2150.42 cubic inches, described under our article **BUSHEL**. By the act of 12 Anne, the coal-bushel is directed to be round, with an even bottom, and to be 19 $\frac{1}{2}$ inches diameter, from outside to outside, capable of containing one Winchester bushel and one quart of water; of which a standard is to be kept in the exchequer, and 36 of such bushels, heaped up, are to make one chaldron. By the act 43 Geo. III. the coal-bushel was directed to be heaped up in the form of a cone, but the exact height, or proportion thereof, to the base or top of the bushel (19 $\frac{1}{2}$ inches) not being fixed in this act, the principal land coal-meters have, from careful and long continued observations of the custom or practice of measuring coals, fixed the height of the cone at 7 inches above the top of the bushel; this we learn from Mr. Robert Vazie, a gentleman who has laudably taken much pains, in endeavouring to introduce a bow-gage to coal-bushels, nearly similar to the bail or handle of a water-pail, which should at all times, by being lifted up and swept over the bushel, determine the proper quantity of the heaped part, which is now left to the discretion of the fillers, subject to the inattention or partiality of the meter, who is, or ought to be, standing by. According to these data, the content of the coal-bushel itself ($= 1\frac{1}{4}$ corn bushel, as above) will be 2217.62 cubic inches, its depth inside varying, from about 8 to 9 inches, according to the thickness of the wood in the sides, it being the out-

side diameter which is fixed by law, on account of the heaping up.

A cone of 19 $\frac{1}{2}$ inches diameter, and 7 inches high, will contain 696.8482 cubic inches, and therefore 2914.47 cubic inches, will be very nearly the cubic content of a heaped bushel of coals, $= 1.6866$ cubic feet, $= .062467$ cubic yards, $= 5.866565$ cubic links, $= .477126$ steres or new wood measures of France, $= \frac{1}{2}$ chaldron, $= 4$ coal pecks, $= 1.3553$ malt, or Winchester bushels struck. From the above calculations, our readers will see, what relation the coal bushel bears to other measures. By the late acts for regulating the delivery of coals in and near the metropolis, every waggon or cart used in delivering of coals, is required to have a lawful bushel with it, edged with iron, to prevent wear, and sealed; and using others or altering such bushels, incur a forfeiture of 50*l*.

COAL, Cannel, or Candle. See **COAL Supra** and **AMPELITES**.

COAL Canal, or *Somersetshire Coal Canal*, commences in the *Kennet* and *Avon* canal, about 3 $\frac{1}{2}$ miles above the city of Bath, and proceeds S.W. in two branches, with rail-way extensions to the collieries N.E. of Mendip hills. See **CANAL**.

COAL-fish, in *Ichthyology*. See **GADUS Carbonarius**.

COAL-land, in *Geography*, a village in the county of Tyrone, Ireland, where the coal works are carried on with tolerable success. In 1800, there were five pits working industriously, and the works were not much impeded by water. There is, however, great want of encouragement; and the canal, which was made at the public expence, to the Tyrone collieries called Blackwater, has been so much neglected, that it is choked up with mud and weeds. Coal-land is about 3 miles W. from Lough-Neagh, and 4 N. from Dungannon. M'Evoy's Account of Tyrone. See **CANAL**.

COAL Measures, a term among miners, for the strata most frequently alternating with beds of coal; these often consist of argillaceous shale, and contain numerous impressions of vegetables upon them, of which there was a very curious collection in the late sir Ashton Lever's museum. See our article **COAL Supra**.

COAL Measuring. In the pool or port of London, coals are measured out of the ship into the barges, or lighters, in a vessel or low tub, called a vat, holding nine bushels (see **VAT**), which is heaped up by the porters who fill, until the sworn meter, who is always in attendance, is satisfied with the justice of the measure, and directs the vat to be emptied over the ship's side into the room of the barge, &c. below. Out of these barges, &c. the coals are again measured by a standard coal bushel (see **COAL-bushel**), in the presence of another sworn meter, called a land meter, and are emptied out of the bushel into sacks, for delivery to the buyers; a few years ago, this last process was improved as follows:

Plate XIV. of Mechanics, represents a machine for measuring coals, for which Messrs. Simeon and Thompson took out a patent in the year 1803. The machine, from which the drawing is taken, was erected in 1803 at the Red-croft coal wharf, near London bridge, and has been at work ever since with great success near the water-works. It is erected before the wall of the coal warehouse, and communicates with the second floor, by a large opening in the wall. The barges, containing the coals, are brought under the wall of the warehouse, which is by the water-side; they are filled into buckets, and then drawn up by a machine into the house, where they are emptied into a wheel-barrow, and thus conveyed to the stage, A, fig. 1, in the floor of which

the bushels, B, B, B, are placed; these bushels are of cast-iron, of the dimension directed by act of parliament; they have moveable bottoms, opening downwards on hinges toward the wall of the house, and are shut by a chain, which is fastened to the bottom, opposite the hinges, and comes up through a tube, *a*; the other end of the chain goes over, and is fastened to a wheel of cast-iron, F, mounted on a shaft, which carries similar wheels for the other two bushels; it turns on a pivot in the wall, F, at one end, and on another, working in a collar, supported in the wainscoting, G, which forms the other end of the room; the shaft projects some distance through this partition, and has a wheel, H, fixed on it, round which a rope, I K, passes; the end, K, of this rope has a ring tied to it, which is hooked on a pin in the wall, which pin is adjustable by a screw, as shown in *fig. 2*, so that when the ring is hooked on it, the bottoms of the bushels shall be close shut; *b d*, *fig. 2*, is an iron frame screwed to the wall, in which a square piece of iron, *e*, carrying the pin (on which the ring is hooked) slides; *f* is a screw turning in the frame, and passing through the piece *e*, which is tapped, so that by turning the screw by a winch, put on the square at its upper end, the pin can be raised or lowered.

The chains, D, *fig. 1*, have each a screw-link in them, by which the bushels can be all made to shut close at the same time. Beneath each bushel is a wooden hopper, L, into which the coals are emptied when the bottom of the bushel is opened, and the sacks are hung to this hopper to receive the coals; there are two small hooks at the back of the hopper, to which the mouth of the sack, M, is hooked; *b* is an iron bar, with a hook at each end, to fall on to the sack; two small cords are tied to this bar, which pass over two pulleys, and are both fastened to a ring that is hooked on a pin, driven into the hopper, in order to keep the sack's mouth close up to the hopper.

The operation of the machine is as follows: the coals are filled into the bushels by three men, and are heaped up until they touch the plummet, *d*, suspended by a chain from the ceiling; when the coal-meter, who sits before the desk, N, sees, through the window, that they are properly filled, he takes the rope, I, with one hand, and with the other slips the ring, at the end of K, off the pin, as before described; the weight of the coals, resting on the bottoms of the bushels, then causes them to open, and the coals fall into the sacks beneath; he holds down the rope, I, until the bushels are all emptied, then lets it return, and hooks the ring on the pin. The bottoms of the bushels are made to shut, by one of the spaces between the arms of each wheel, E, being filled with lead, which is equal to about half the weight of the coals; when the sacks are filled, they are placed in a hand-barrow, and are wheeled into the waggon, the stage, R, being just the same height from the ground, as the floor of the waggon, which is backed up against it.

COAL-Mines. See **COAL**. By 10 G. II. c. 32, if any person shall wilfully and maliciously set on fire any mine, pit, or delph of coal, or cannel-coal, he shall be guilty of felony, without benefit of clergy. By 13 G. II. c. 21, if any person shall convey water to any coal-work, with design to destroy or damage the same, he shall pay to the party aggrieved treble damages with costs, recoverable in any court of record at Westminster. By 9 G. III. c. 29, any person demolishing engines, waggon-ways, bridges, &c. belonging to coal-mines, or causing the same to be done, shall be guilty of felony, and be transported for seven years: the prosecution on this act being within 18 months. By 39 and 40 G. III. c. 77, any person, destroying or damaging mines or roads leading to or from the same, shall be deemed

guilty of a misdemeanor, and may be imprisoned, on conviction, for any time not exceeding six months. Colliers and others, who wilfully and obstinately work in a manner contrary to their agreements, or who do not fulfil their contracts, shall, on conviction, upon the oath of one witness, before one justice, forfeit not exceeding 40s., and upon non-payment, be committed to the common gaol without bail, for a time not exceeding six months, or till such penalty and costs shall be paid; and the contract shall become void. Persons convicted of fraudently walling or stacking coal, &c. shall, on conviction, by confession or oath of one witness, before one justice, be committed to the common gaol or house of correction, for any time not exceeding three months. If any person shall steal coals or implements, not exceeding the value of 5s., he shall, for the first offence, forfeit not exceeding 10s. over and above the costs, or be committed to hard labour for one month; for the second offence, not exceeding 20s., or be committed to the house of correction for three months; and for the third, or any future offence, not exceeding 40s., or be committed to hard labour for 6 months. All prosecutions under this act shall commence within nine months after the offence is committed.

COAL, Old, an inferior sort of charcoal, made in Kent, and other places, from the roots of trees and underwood, for sale to the foundries, and others, in London, who use it for some common purposes, as a substitute for charcoal.

COAL-Orton, or *Cole-Orton*, a rectory in the hundred of East-Goscote, in Leicestershire; it is situate very high, yet its coal-mines have attracted the rail-way extensions of canals, in two different directions, *viz.* the *Leicesters* and the *Ashby-de-la-Zouch*. See **CANAL**.

COAL, Patent, is applied to a substance manufactured in Millbank Street, Westminster, under a patent, granted to Mr. Chabannes, (see *Repertory of Arts*, XV. 367.) ; it consists of the smaller parts, fitted out of the sea-coals, used for culinary purposes, before they are sold, mixed up with a certain proportion of dirt and sweepings of the streets, which mixture is watered and tempered together, until fit for making into small bricks, of which great numbers are set to dry in a large open-boarded shed. One or two of these coal-bricks, put into a coal-fire, are said to continue the intensity of its heat for a long time. See **COAL-balls**.

COAL-Port, the name given by the late Mr. William Reynolds, to a new town which he founded on the banks of the Severn river, at the entrance of the Shropshire canal. See **CANAL**.

COAL, Small, is a sort of charcoal, prepared from the spray and brush-wood, stripped off from the branches of coppice-wood, sometimes bound in bays for that purpose, and sometimes prepared without binding.

The wood they dispose on a level floor, and, setting a portion of it on fire, they throw on more and more, as fast as it kindles; whence arises a sudden blaze, till all be burnt that was near the place. As soon as all the wood is thrown on, they cast water on the heap from a large dish or scoop; and thus keep plying the heap of glowing coals, which stops the fury of the fire, while, with a rake, they spread it open, and turn it with shovels till no more fire appears. When cold, the coals are put up into sacks for use. Small coal was formerly much more in use in London than it is at present. The lightings of charcoal are called *charmin* by the London dealers.

COAL-foot. See **SOOT**.

COAL spirits. Coals distilled in a retort not only afford a phlegm and black oil, but a spirit, or calcous matter, which is

apt to force the lute and break the glasses, now known to be hydrogen gas: bladders may be filled with this inflammable air, which may be kept a considerable time. If the bladder be

pierced with a pin, and squerzed near the flame of a candle, the gas will take fire, and afford an amusing spectacle. See Phil. Trans. N. 452. sect. 5. See DAMPS and Gas-Lights.
COAL-tar. See TAR.

Coalbrookdale

COALBROOK DALE, in *Geography*, a village of Shropshire, about 13 miles from Shrewsbury, which exhibits to the traveller the beneficial effects of manufacture and commerce, in its celebrated iron works, as well as a variety of romantic scenes. The river Severn winding between high wooded hills, opposite to the forge of Broseley, is crossed by a bridge of one arch, 100 feet in length, and formed entirely of cast-iron, with strong stone abutments, which presents at once a striking

effect in landscape, and a stupendous specimen of the powers of mechanism. This was the first iron bridge erected in England, and was cast in 1779, under the direction of Mr. Abraham Darby. Besides the communication of these works with the Severn river, they have a branch of the Shropshire canal extended to connect with their rail-ways. See CANAL.

Coating

COATING, in its general sense, denotes the covering of a body, or the spreading of one substance over another; and this is practised, with various views, in civil economy, in the arts, and in some scientific branches of knowledge. Thus, human beings are covered with various garments, both for defence and for ornament; houses, vessels, and most works of wood, are covered with paint, or pitch, or lead, or copper, or other matter, for the same purposes; the baser metals are covered with the richer, silver is coated with gold, copper with gold or silver in ornamental works; iron or copper is coated with tin for culinary purposes, in order to prevent the rusting of the former, and the noxious effects of the latter; and so forth. See the practical methods of performing these operations under the articles PAINTING, PLASTERING, GILDING, SILVERING, TINNING, &c.

COATING, in *Chemistry*, is used principally for the purpose of defending certain vessels from the immediate action of fire; thus, glass retorts and the inside of some furnaces are coated with various compositions. See LORICATION, and LUTING.

COATING, in *Electricity*, means the covering of electric bodies with conductors, or the latter with the former, or, lastly, electrics with other electrics. Electrics are coated with conductors, for the purpose of communicating to, or removing from, their surfaces, the electric fluid in an easy and expeditious manner; otherwise an electric body, on account of its non-conducting property, cannot be electrified deprived of the electric fluid, without touching almost every point of its surface with an electrified or other body. This coating generally consists of tin-foil, sheet-lead, gilt paper, gold leaf, silver leaf, or other metallic body, either in the form of a thin extended lamina, or in small grains, such as brass filings, and leaden shot. The coating may be fastened to the surface of the electric by means of paste, glue, wax, or other adhesive matter. In lining Leyden phials, care should be had not to fasten the coating (if it consists of brass filings or gold leaf) with varnish; for this is apt to take fire on making the discharge. But in some cases the metallic coating is merely laid upon the electric; for instance, in certain experiments, a piece of tin-foil, or a brass plate, is laid upon a pane of glass, so that after having charged the glass, the coating may be easily shook off; and a Leyden phial is, sometimes, partly filled with leaden shot, which performs the office of an inner coating, and may be easily poured out of it. Also, when two extended parallel metallic surfaces are placed at the distance of about an inch or two from each other, the intervening stratum of air (being an electric) is said to be coated, and may be charged and discharged like a Leyden phial. When the electric is of a very fusible nature, such as sulphur, shell-lac, sealing-wax, &c. a case of it may be coated by pouring it melted upon a metallic plate, or in a cup, which is required in certain experiments. See ELECTRICITY, ELECTROPHORUS, and LEYDEN PHIAL.

In certain cases conductors are coated with electrics, either partially or entirely, for the purpose of preventing the absorption or dissipation of the electric fluid from their surfaces. This is done with varnish, or more effectually with sealing-wax, the latter of which, when the shape and

size of the conductor allows it, may be easily performed by warming the conductor to a certain degree, which is indicated by actual trial, and then rubbing a stick of sealing-wax over its surface.

Lastly, the coating of electrics with other electrics, is principally, if not exclusively, practised with articles of glass; for, since moisture easily adheres to the surface of glass, the insulating quality of the latter is thereby greatly diminished and often annihilated; hence the glass feet of insulating stools, the glass handles of directors, the pillars of some electrical machines, &c. are generally covered with some other electric substance of a resinous quality, which is not apt to attract moisture. The substances principally used for this purpose are sealing-wax and varnish. When the glass article is sufficiently small, the best way of covering it with sealing-wax is, to heat the former, and then to rub a stick of sealing-wax over it, so as to form an equal coat of the wax over the surface of the glass; and this is, by far, the best mode of obtaining the desired object; but when the piece of glass is too large, then the sealing-wax must be dissolved in spirit of wine, and must afterwards be spread over the glass with an hair pencil; having previously wiped the glass perfectly clean and dry. In this case, however, care must be had to use the best rectified spirit of wine, or alcohol; for if impure spirits be used, the solution of sealing-wax, when spread upon the glass, will insulate very imperfectly, or even not at all. Of the dissolved sealing-wax you may lay two, three, or more, coats upon the glass, always allowing one coat to become perfectly dry, before the next is put on.

With respect to the use of varnish, it must be observed, that very few of the common varnishes will answer this purpose in any tolerable degree. This is one, however, which, when properly made, and carefully applied, answers as well as the sealing-wax coating. This varnish, which was long kept a secret, is made in the following manner: Take half a pint of linseed-oil, one ounce of saccharum saturni, and one ounce and a half of litharge. Set them in an iron vessel to boil over a small charcoal fire (*viz.* such as is barely sufficient for the purpose), stirring the materials frequently with an iron spatula or an old knife. As soon as these ingredients are incorporated, add one ounce and a half of prepared amber, and let it continue to boil, stirring the materials frequently, until you find upon trial, that a drop of the liquor, placed between two knife blades, stretches like thick glue, or like turpentine. When this takes place, remove the vessel from the fire, suffer it to cool a little, and then mix spirit of turpentine with it, stirring the whole together, which will thin it; but take care not to render it too thin; for by keeping, in a few days, it will of itself grow thinner. Lastly, keep it in bottles for use. *N.B.* The iron vessel must be much larger than the quantity of ingredients might require, and it must be furnished with a handle, because the oil, &c. in boiling, is apt to swell and will run over, if the vessel be not quickly removed from the fire. The amber is prepared, first, by powdering it; secondly, by melting, or rather charring it, in a shovel over the fire; and, lastly, powdering it again in a mortar. This varnish is used in the same manner as the above-mentioned solution of sealing-wax; but you need not lay on more than one coat of it, or, at most, two.

Cobalt

COBALT, *Kobolt*, Germ. in *Mineralogy*. Cobalt is a metal of a white colour, inclining to bluish, or steel-grey; when tarnished, acquiring a reddish tinge; its fracture is compact, fine-grained, and uneven. Its specific gravity is 8.53. It is attracted by the magnet, and is itself capable of polarity. At a common temperature it is brittle, and easily reduced to powder, but when red hot may be slightly extended under the hammer. It requires for its fusion nearly the same heat as cast iron does. When in the state of oxyd it tinges the saline vitreous fluxes of a deep blue. It

is soluble in nitro-muriatic acid, and the solution forms a blue-green sympathetic ink.

§ 1. *Ores of Cobalt.*

Cobalt occurs, 1st, mineralized by arsenic; 2d, as an oxyd; 3d, combined with arsenic acid; 4th, combined with sulphuric acid.

Sp. I. *Arsenical Cobalt.*

Cobalt is never found pure in the metallic state, but is

always alloyed with arsenic, and often besides contains iron and sulphur, and sometimes nickel, bismuth, and silver.

Of the sub-species only the crystallized (3d sub-species) has been analyzed, and both by Klaproth and Tassaert. The following are the results. Klaproth obtained

Cobalt	- 44.
Arsenic	- 55.5
Sulphur	- 0.5
	<hr/>
	100.0

Tassaert obtained

Cobalt	- 36.66
Arsenic	- 49.
Iron	- 5.66
Sulphur	- 6.5
	<hr/>
	97.82
Loss	- 2.18
	<hr/>
	100.

Similar differences are observed between the analyses of this variety by other chemists, so that it may be considered as allowing considerable range both in the proportion and nature of its constituent parts, without materially affecting its crystallization. It appears, however, from Haüy, that when the crystals display a lamellar fracture, they contain a notable proportion of sulphur and iron. We shall follow Brochant's arrangement of the sub-species.

1. Sub-species. White cobalt. *Weisser Speiskobalt. Cobalt blanc*, (species 2 of Kirwan and Haüy.)

The colour of this mineral, when recently broken, is tin-white, but its surface is generally yellowish, bluish, greyish, or iridescent, like steel that has been heated. It occurs in mass, disseminated, kidney-shaped, and rarely in minute quadrangular tables, or imperfect cubes and octahedrons. Their external lustre is slight, but internally is brilliant and metallic. Its fracture is fine-grained and uneven: when broken, it flies into sharp-edged irregular fragments: when in mass, it contains fine-grained granular distinct concretions. It requires a polish by friction, is brittle and hard: when exposed to the blow-pipe, white cobalt melts with great ease, giving out a white vapour, and a strong arsenical odour, and a white brittle bead of metal remains, which gives a blue colour to glass of borax, when melted with it.

It is found in Norway, at Tunaberg in Sweden, Annaberg in Saxony, and also, rarely, in Swabia and Stiria. In Saxony and Norway, it is contained in beds of micaceous schistus, accompanied by the red earthy cobalt, quartz, hornblende, and pyrites.

2. Sub-species. Dull-grey cobalt. *Grauer Speiskobalt. Cobalt gris*, (sp. 1. of Kirwan and Haüy.)

The colour of this mineral is a clear steel-grey, but by exposure to the air it acquires an iridescent tarnish. It occurs in mass or disseminated, sometimes in kidney-shaped or clustered masses, and very rarely in specular laminae. Its external lustre is very feeble, but internally it exhibits a bright metallic lustre. Its fracture is compact, generally even, but sometimes passing into flat-conchoidal; its grain is remarkably fine and close. Its fragments are sharp-edged, indeterminate. It is not so hard as the preceding, and is less brittle. Its specific gravity varies from 4.3 to 5.3, or even 5.5. It gives a bluish-grey metallic streak.

When exposed by itself to the blow-pipe, it gives out an arsenical vapour and smell; but seldom fuses: when treated

in the same way with borax it gives the flux a blue colour, and is reduced to a metallic globule.

A specimen from Cornwall was analysed by Klaproth, who procured from it about 20 per cent. of cobalt, 24 of iron, and 33 of arsenic, the remainder consisting partly of bismuth and sulphur, together with earthy matter. Some varieties have also been found to contain nickel and silver. It is found in Saxony, Bohemia, Swabia, and Hungary; also in Stiria, France, Norway, and Cornwall.

3. Sub-species. Bright white cobalt. *Glaux Kobalt. Cobalt éclatante*.

The colour of this mineral is tin-white, but tarnishes to greyish, whitish, or iridescent. It is found in mass, disseminated or investing, or of particular shapes, as clustered, kidney-shaped, globular, or crystallized in cubes or octahedrons. The crystals are middling-sized or small, their surface is commonly smooth and brilliant, and marked with striæ on the sides of the primitive cube. The fracture of the crystals is lamellar, that of the other varieties is fine-grained, uneven, or radiated. When in mass it presents granular, or lamellar, or testaceous distinct concretions. Its hardness is somewhat inferior to the preceding sub-species: when pulverized, it is of a steel-grey colour. Sp. gr. 6.2 It is brittle, and easily frangible.

Before the blow-pipe, it burns with a faint white flame, disengaging arsenical vapours; it then becomes black, is attracted by the magnet, and is, with the utmost difficulty, reduced to a metallic globule. It often contains as much as 50 per cent. of reguline cobalt.

This is the commonest of all the ores of cobalt: it occurs for the most part in primitive mountains, together with the other species of cobalt ore, with vitreous, red, and native silver, with arsenical and cupreous pyrites, &c. It is met with in various parts of Germany; also in Sweden, Norway, Stiria, and Cornwall.

Sp. II. Earthy Cobalt.

Of this there are the four following varieties:

Var. 1. Friable black cobalt. *Schwarzer Kobalt muhn. Cobalt terreux noir friable*.

The colour of this is black, bluish, brownish, or greyish black. It is without lustre, has a loose earthy consistence, is friable and meagre, stains the fingers in a slight degree, and gives a brightish streak. It is soluble in muriatic acid; tinges borax blue, and very rarely shews any indications of sulphur or arsenic, when treated by the blow-pipe.

Var. 2. Indurated black cobalt. *Verharteter schwarzer kobalt. Cobalt terreux noir endurci*.

In colour it resembles the preceding, except that it is sometimes of a dark greenish black. It occurs massive, disseminated, investing, kidney-shaped, clustered, or in veins. It is dull, but takes a polish by friction. Its fracture is earthy and compact, passing into flat-conchoidal. It possesses a moderate degree of hardness. Sp. gr. from 2. to 4. With nitric acid it gives a red solution, and a bluish-green one, with muriatic acid. It has not been accurately analysed, but consists of oxyd of cobalt, with a small variable proportion of arsenic and sulphur mixed with vitreous silver ore, oxyd of iron, and clay.

This, and the preceding variety, are always found together; but the indurated is by much the most rare. It is found in Saxony, Thuringia, Swabia, and the Tyrol.

Var. 3. Yellow cobalt. *Gelber erdkobalt. Cobalt terreux jaune*.

Its colour is that of faded straw, passing into yellowish white, and often streaked with brick-red. It is found in mass, disseminated or investing. It is without lustre, has a

fine-grained earthy fracture, gives an unctuous streak, and is soft and friable.

It is infusible *per se*, gives a feeble, arsenical odour, and communicates a deep blue tinge to borax: but when mixed with iron, as it often is, the colour is greenish.

This is one of the rarest of the ores of cobalt. It has hitherto been found only in Thuringia, Wirtemberg, and Dauphiné.

Var. 4. Brown cobalt. *Brauner erdkobalt. Cobalt terreux brun.*

Its colour is a clear liver-brown, passing into grey, yellow, and black. It occurs in mass or disseminated; it is dull, but acquires a greasy lustre by friction. Its fracture is fine-grained, earthy. It is easily broken, being almost friable. It has been analysed, but appears to be the connecting link between the second and third varieties. When thrown on burning coals, it generally gives out an arsenical odour.

Sp. III. Red Cobalt.

Of this there are two varieties.

Var. 1. Crystallized. *Kobaltblute. Fleurs de Cobalt.*

The usual colour of this mineral is peach-blossom-red, passing into cochineal and greyish-red; by exposure to the air it becomes paler, and almost white. It is found very rarely in mass, or disseminated, and still seldomer clustered, or kidney-shaped; its most usual state is that of a thin crystalline covering, or minute druses of crystals. The forms which it generally affects are rectangular tables, or tetrahedral acicular prisms, or hexahedral prisms terminated by dihedral summits: these figures, however, are not often determinable, on account of the minuteness of the crystals, and their tendency to form radiates and globular groupings. The surface of the crystals is smooth and brilliant, and their fracture lamellar. The fracture of the other kinds is radiated, passing into fibrous. It is translucent, and often, when crystallized, semi-transparent.

Before the blow-pipe it gives a faint arsenical odour, and becomes of a dark-grey colour; it is almost infusible by itself, and gives a beautiful blue tinge to borax.

Var. 2. Earthy. *Kobaltbeschlag. Cobalt terreux rouge pulverulent.*

The colour of this is the same as that of the preceding variety. It occurs in a pulverulent or indurated state, disseminated through, or investing other minerals, and occasionally in mass. It is dull, opaque, and has an uneven earthy fracture. In other respects it agrees with the preceding.

Sp. IV. Native sulphat of cobalt. *Naturlicher kobalt-viurcol. Sulfate de cobalt natif.*

At Herregrund, near Neusohl in Hungary, is found a saline substance, in the form of translucent stalactites, of a pale rose-red colour. It was at first supposed to be sulphat of manganese, but from an analysis of Klaproth, it appears to be a pure sulphat of cobalt.

§ 2. Reduction of the Ores and Analysis.

Cobalt is never employed in manufacture in the reguline state; the sole use of this very valuable metal being to give various shades of blue colour to glass and enamel, and when thus employed, it is in the state of oxyd. In this state it forms either *zaffre*, or *smalt*, when prepared in the method, which will be described in the next section.

Many of the cobalt ores are complicated, and difficult to be analyzed completely, nor is it easy to obtain the cobalt alone from them in considerable purity. The metals naturally varied with cobalt are the following: 1st, arsenic, generally

in very large quantity, part of which is in the reguline state, and, as appears, another part is in the state of arsenic acid, which, uniting with the oxyd of cobalt, forms an arseniat of cobalt, that has often been mistaken for the pure oxyd. The entire separation of the two is extremely difficult. 2d. Nickel exists with many cobaltic ores; and being soluble in the same menstrua, it is not easily separated. 3d. Iron, in variable quantity, is found with most of the ores of cobalt, and is hurtful, as it impairs and degrades the fine blue for which alone cobalt is valued. 4th. Manganese, which is a still worse admixture. 5th. Copper, in small quantity, is sometimes found, which, however, does not much injure the cobalt.

An imperfect analysis of the common cobalt ores, and which merely has for its object the extraction of the cobalt, is made in the following way: Mix the ore, in fine powder, with charcoal or saw-dust, and roast it in a low red heat, till the arsenic is driven off, and no arsenical fumes are any longer perceived. Calcine the residue some time longer with a strong red heat, and in an open fire, and then mix it with about four parts of a saline, reducing flux, (such as that composed of equal parts of tartar and carbonat of potash) and heat it in a roomy covered crucible, at first moderately, till the first swelling of the materials has subsided, and then for a quarter of an hour in a heat fully sufficient to melt iron. When cold, a button of reguline cobalt is found beneath a mass of scorix of an intense blue-black colour. From 100 grains of the Tunaberg ore, Klaproth obtained in this way 44 grains of regulus of cobalt, which, however, must have been still very impure, retaining iron and a portion of the arsenic. It may be further purified by alternate deflagration with nitre, and reduction with a saline carbonaceous flux, repeated two or three times, in the way that Lampadius and Tromsdorf have employed with smalt, as will be presently mentioned.

The reducing flux for cobalt ore, employed by Beaumé, is the following: Mix 1 oz. of the roasted ore with 3 oz. of black flux, and $\frac{1}{2}$ oz. of carbonat of potash, cover it when in the crucible with about 1 oz. of salt, and heat the whole, at first slowly, and afterwards very briskly for a quarter of an hour.

But, for the purposes of mere analysis, where all the constituent parts of the ore are required to be known with as much precision as possible, these methods are much too inaccurate to be depended on, and recourse must be had to the more tedious and difficult analysis in the humid way. The process given by Tassaert (*An. de Chim.* tom. 28.) is highly valuable and instructive.

The method given by Lampadius, of purifying cobalt by fusion is the following: Project in a red-hot crucible a mixture of 4 oz. of zaffre, 2 oz. of nitre, and $\frac{1}{2}$ oz. of charcoal. A strong arsenical smell is perceived in the process, and a blackish-grey mass is left, which is to be again mixed with charcoal and nitre and deflagrated as before: then throw in the crucible 2 oz. of black flux, and heat it intensely for an hour. This gives a tolerably pure regulus of cobalt, weighing 6 drams. Powder it, and mix it with 1 dram of nitre, and as much manganese; put it into a luted double crucible, and heat it for an hour in a forge-furnace. The metal, by this operation, loses all its iron and is nearly pure.

Tromsdorf's process is the following: The zaffre, or smalt, is to be twice detonated with nitre, then washed in hot water, which carries off the arsenic now united with the potash of the nitre, and the residue is to be digested in dilute nitric acid, which will only touch the cobalt and leave the iron. The nitrous solution may then be decomposed by an

alkali, and the purified oxyd of cobalt, thence resulting, may be afterwards reduced if required.

§ 3. Preparation of Zaffre and Smalt, or Azure.

All the zaffre and smalt of commerce are prepared in some parts of Germany, and particularly at Schneeberg in Misnia, which affords a very lucrative trade to Saxony. The following is the method of preparation as given by Kunckel. (See *Neri's Art de la Ferrerie*.) The cobalt ore, broken in small pieces, is spread on the hearth of a furnace, like a baker's oven, so constructed that the flame of the wood is reverberated on all sides over the surface; which soon heats it red-hot. A very dense arsenical vapour then arises, which is conveyed from the furnace into a horizontal wooden square trough, or chimney, sometimes of the enormous length of a hundred fathoms, where most of the arsenic is condensed and collected for sale. The cobalt ore is calcined for some hours, till it scarcely emits any more vapours, after which it is taken out, ground to fine powder, replaced in the oven, and calcined a second time, and then again ground and passed through a very fine sieve. This powder is then mixed with about twice its weight of powdered flint or quartz, wetted to the consistence of stiff mortar, and rammed into small barrels, where the mass soon acquires a stony hardness, and is then the *zaffre* of commerce. The reason of using the flints appears to be partly to dilute the cobalt ore, and partly for some purpose of concealment; the exportation of the simple calcined ore being forbidden under heavy penalties.

Smalt, sometimes also called *azure blue*, when finely powdered, (which must not be confounded with the true *azure*, or *lapis lazuli*) is an intensely deep blue glass, made of the calcined cobalt ore and the common vitrifiable fluxes, which is used as a colouring matter for a variety of purposes. The intensity of colour of course depends on the proportion of roasted cobalt ore which it contains, regard being had to its quality, and the proportion of oxyd of cobalt which it is estimated to contain. On an average about equal parts of the roasted ore of potash, and of ground flints are used. This mixture is first *fritted*, and then melted in pots similar to those of glass-houses, and about ten or twelve hours of fusion are required. When the glass is thoroughly fused, it is laded out and dropped into cold water to crack it in every direction, and then ground in a mill made of a very hard stone. At the bottom of the glass-pots a quantity of regulus of bismuth is always found, lying under a mixed alloy of arsenic, iron, and copper.

The grinding of the blue glass is a work of much difficulty, and different degrees of fineness of the powder are obtained by subsequent washing and sifting.

Smalt is a valuable colour, on account of the fine body which it possesses; and being indestructible in any heat, it is useful for all enamel colours, but it will not mix with oil colours, and therefore can only be partially used. Starch is slightly coloured with it to give a small degree of blueness, which corrects the yellow hue which linen and cotton acquires by being worn.

Zaffre is also prepared in Bohemia, Wirtemberg, Silesia, and Lorraine, but the Saxon is preferred.

The oxyd of cobalt contained in the zaffre is still intimately mixed with a small portion of arsenic, partly as arsenic acid, and partly as oxyd of arsenic. If zaffre is digested in liquid caustic ammonia, a red solution is formed, which, on evaporation, deposits a yellow powder, which is a mixture of the oxyds of cobalt and arsenic. If zaffre is boiled in water, a solution is also obtained, which is sensibly acid, and was thought by Brugnatelli to indicate the existence of a co-

baltic acid, but Darracq has shewn it to be an arseniate of cobalt.

§ 4. Chemical Properties of Cobalt

Cobalt, when perfectly pure, has a steel-grey colour, not very resplendent, and when slowly cooled, has somewhat of a reticulated texture. It melts at about the fusing point of cast iron.

Cobalt, when heated strongly in contact with air, is converted into a black oxyd, with an increase of about 18 parts on 100; hence 100 parts of the oxyd contain 84.75 of metal, and 15.25 of oxygen. When it retains any arsenic, the colour is reddish.

This metal burns in oxymuriatic acid gas, with a bright white flame.

The sulphuric acid dissolves cobalt with difficulty, but its oxyds more readily. If zaffre, or which is better, the wet precipitate from nitrat of cobalt by carbonat of potash, is digested with sulphuric acid, and the mixture evaporated nearly to dryness, the residue digested with hot water, gives a solution of sulphat of cobalt, which, by slow evaporation, affords the salt in crystals, that are of a fine red when the metal is pure, but greenish when it contains nickel. This salt is soluble in 15 parts of boiling, and 24 parts of cold water.

Nitric acid dissolves cobalt or its oxyd copiously and with great ease by digestion in a moderate heat. The solution is red, or claret-coloured, or yellow, if it holds iron. It scarcely can be brought to crystallize, but by evaporation to dryness and calcination, it leaves a dark red or violet oxyd.

Muriatic acid acts with great difficulty on cobalt, and can scarcely be made to dissolve it, unless by repeated evaporations to dryness and affusion of fresh acid. But it dissolves the oxyds of this metal with much more ease when assisted by heat. The solution is of a rose-red, but when evaporated to dryness and warmed, it acquires a beautiful blue-green, which more approaches to blue in proportion as the solution is free from iron. This singular property of the muriat of cobalt was first discovered by Hellot, and used in making a beautiful *sympathetic ink*, the properties of which have engaged much of the attention of chemists. If the solution be considerably diluted, characters traced by it on paper are scarcely visible when cold, but when held near the fire, they very speedily assume a beautiful blue green, which colour again totally disappears when cold, and may be made to re-appear at pleasure by the same means. The paper, however, should not be heated more or longer than is necessary to produce the full effect. It is found, that not only the pure muriat of cobalt, but any solution of this metal into which muriatic acid, or a muriatic salt, enters, will have the same effect. Hence the commonest method of making this sympathetic ink, and that employed by the inventor, is, to digest zaffre in a moderate heat, with a mixture of about three parts of nitric and one of muriatic acid, diluted with as much water, till a high claret-coloured solution is formed, which should then be diluted with as much water as possible, to prevent the paper from being corroded by the acid. But a much more concentrated solution may be made, which shall not injure the paper, in the following way: Boil some moderately dilute nitric acid or zaffre, till much of the cobalt is dissolved out of it, then add to it any alkali as long as any precipitate takes place; pour off the clear liquor after standing some time, wash the sediment with hot water, and throw it on a filter. Take the sediment which is left on the filter, and put it, while still wet, into a glass flask, and boil

it with distilled vinegar, which will readily dissolve it, and make a rose-coloured solution, which may then be made into a fine sympathetic ink, by dissolving in it some common salt or sal-ammoniac.

It has been mentioned that the colour of the common cobaltic sympathetic ink is green, and when made simply by dissolving the soluble part of zaffre in nitro-muriatic acid, it is generally a pale grass green, but in proportion as the cobalt becomes purer, the colour approaches to a bright blue green. This is probably owing to the separation of iron which the common zaffre contains in abundance, and which may be effected more or less perfectly in various methods. The simplest (though not the most economical) is to add to the solution very gradually carbonate of potash as long as the precipitated oxyd is rose-coloured, and to cease when it begins to have a yellow ochery hue; for the former consists chiefly of the cobalt, and the latter chiefly of the iron. Then by collecting, washing, filtering, and re-dissolving the rose-coloured precipitate in the nitric or acetic acid, a much purer solution is obtained, which contains very little iron, and gives a blue-green sympathetic ink, when any muriatic salt is added. Another way of separating most of the oxyd of iron is to evaporate the nitrous solution nearly to dryness, and to expose it for some time in a shallow vessel to the air, by which much of the iron will be rendered insoluble, and subside as a red ochre, whilst the cobalt will remain in solution. Or else the acetated solution of both metals may be alternately evaporated to dryness, and the soluble part, re-dissolved by fresh acetic acid, for two or three times successively, by which the iron will gradually separate, and the cobalt alone be left.

But to obtain perfectly pure cobalt, separate from arsenic, bismuth, iron, and other impurities, is more difficult, for in the above-mentioned processes the arsenic acid and oxyd contained in the cobalt ore must accompany the cobalt and be retained in all the solutions. We should therefore recommend the following method: Digest a quantity of zaffre with nitric acid diluted with about three times its weight of water, and boil them for some time. After standing for a while pour off the clear solution and evaporate it nearly to dryness. Then dilute it pretty largely with water, which will cause the bismuth, if any, to subside. Then neutralize any excess of acid in the filtered solution by any alkali, avoiding to precipitate any of the metal which it contains, and add, cautiously by drops, some of a solution of nitrated lead (made by dissolving the crystals of this salt in water) as long as any precipitate falls down. This latter is arseniate of lead, and by this means all the arsenic acid of the zaffre will be removed. Then entirely decompose the clear solution by caustic potash, collect and wash the precipitated oxyd put into

a phial, and add to it some caustic ammonia, which will dissolve only the oxyd of cobalt. From this ammoniacal solution all the oxyd may be again separated either by evaporation to dryness, or by boiling with caustic potash, and a very pure black oxyd of cobalt is left, which may be reduced to the metallic state by being heated intensely in a covered crucible lined with charcoal; or it may be dissolved in the several acids. This method, however, is expensive, on account of the quantity of ammonia employed, but it is difficult to exclude the iron totally by any other method.

A triple salt of cobalt, nitric acid, and ammonia, is made by adding ammonia to nitrate of cobalt, which may be crystallized.

The fixed alkalies have little or no action on cobalt or its oxyds in the moist way, but ammonia dissolves the oxyds largely, as already mentioned.

Tincture of galls give a yellowish white, and prussic acid a green precipitate to the solutions of cobalt when free from iron.

Sulphur unites with great difficulty to cobalt by fusion, but the hydrosulphurets and liver of sulphur readily dissolve this metal. Hydrosulphuret of potash added to the solutions of cobalt gives a very black precipitate, which an excess of the hydrosulphuret again dissolves. Cobalt ore fused with liver of sulphur is dissolved thereby, and a brilliant metallic looking mass is produced, which deliquesces totally by exposure to air, and falls into a dark liquid.

None of the possible alloys of cobalt deserve any particular notice, for this metal has only a single use in the arts, namely, that of giving a blue colour to vitrescent compounds when its oxyd is melted with them, and this colouring power is so intense, that a single grain of the pure oxyd (or zaffre in proportion) will give a very deep blue to half an ounce of glass. When the glass contains much more than this proportion, the body of colour is so intense as to render it nearly opaque, and hence, too, it is of use in forming the black glasses and enamels.

The affinities of cobalt are stated to be in the following order, *viz.* the gallic, oxalic, muriatic, sulphuric, tartareous, nitric, phosphoric, acetic, arsenic, and carbonic acids, and ammonia. We may add, however, that the difficulty of obtaining pure cobalt, and the variety of metals with which it is usually alloyed, render this order of affinity somewhat doubtful.

COBALT is also used by some to express that suffocative vapour or damp in mines, which often proves fatal to the miners. It is common among the Germans, to say on this occasion, that the cobalt rose and choked them. See DAMPS.

Coke

COKE, or *Coak*, denotes pit-coal or sea-coal charred. For the exciting of intense heat, as for the smelting of iron-ore, and for operations where smoak would be detrimental, as the drying of malt, fossil coals are previously charred, or reduced to coaks, that is, they are made to undergo an operation almost similar to that by which charcoal is made. By this process coals are deprived of their volatile parts, nothing remaining except the carbon and earthy impurities. The great quantities of coal dust, or small coal, collected at the numerous

pits in the neighbourhood of Newcastle, would soon become a great incumbrance, were it not that an admirable method has been discovered, not only to prevent the inconvenience, but to turn it, with a little modification, into an article of commerce and advantage, by preparations as simple as they are ingenious. Coal, in this pulverized state, is not proper for chamber fires, because it falls through the bars of the grates, or extinguishes the fire by falling upon the ignited

cinders, in such a mass, that no air can get between to assist the combustion. This small coal is, therefore, proper in this state only for some purposes in glass-houses, lime or brick kilns, forges, &c. The consumption for these purposes is indeed very considerable, but is not nearly equal to the quantity produced by the pits, notwithstanding the great care that is taken to keep the coal in large pieces; besides, some kinds are liable to crumble into small-coal upon receiving the least shock: means have, therefore, been sought to render this coal proper for other purposes. That property, which belongs to the best coal, of agglutinating and forming a single mass, when in a state of combustion, naturally suggested the idea of endeavouring to consolidate considerable quantities of this coal dust, or small coal, by means of a great fire. To effect this it is put into a kiln, in a great degree similar to a lime-kiln, which is previously well heated with large pieces of coal. The small-coal then runs together, and forms a mass, without losing any large portion of its valuable qualities. When the ignited mass is completely red, large pieces of it are pulled out with iron rakes (such as are used in the copperas works), and laid separately on the ground, where they are very soon extinguished; these pieces are firm, though porous, and are excellently adapted for smelting iron, and other ores, in high furnaces. This simple and ingenious contrivance has given birth to several new branches of industry and commerce. The coal, thus prepared, is used in a great number of manufactories, where a draft or blast is used, as a substitute for charcoal, to which it is in most instances superior, as it produces a stronger, more equal, and longer continued heat. Such is the method of coak-making at Newcastle, and other places. That pursued in the great iron-works at Carron, near Falkirk, in Scotland, being so completely different, our readers will excuse our giving an account of this also. The business is conducted there in the open air, and in the most simple manner; a quantity of large coal is placed on the ground in a round heap, of from 12 to 15 feet in diameter, and about two feet in height; as many as possible of the large pieces are placed on their ends, to form passages for the air; above them are thrown the smaller pieces and coal dust, and in the midst of this circular heap, is left a vacancy of a foot wide, where a few faggots are deposited to kindle it. Four or five apertures of this kind are formed round the ring, particularly on the side exposed to the wind; there is, however, seldom occasion to light it with wood, for other masses being generally on fire, the workmen most frequently use a few shovels of coal already burning, which acts more rapidly than wood, and soon kindles the surrounding pile; as the fire spreads the mass increases in bulk, puffs up, becomes spongy and light, cakes into one body, and at length loses its volatile parts, and emits no more smoke. It then acquires an uniform red colour, inclining a little to white, in which state it begins to break into gaps and chinks, and to assume the appearance of the under part of a mushroom; at this moment the heap must be quickly covered with ashes, of which there is always a sufficient provision around the numerous fires, where the coak is prepared. This method of throwing a large quantity of ashes on the fire, to deprive it of the approach of air, is similar to that used in making charcoal, which is covered over with earth; the result is also pretty much the same, the pit-coal thus prepared being light and porous, and producing the same effect in high furnaces as charcoal. This is a quality of extreme value; since, by means of charred-pit-coal, founderies may easily be established, in places where the want of wood for charcoal, would otherwise render it necessary to abandon even the richest mines of iron.

The simple method above described being found to consume much of the best qualities of the coke, owing to the

too free access of air during the process; many years ago a method was introduced, of distilling, or charring coals, in close vessels, by the heat of another fire externally applied, and by which also the liquid bituminous matter, or coal-tar, was separated and condensed; the value of which, as a substitute for paint in rough works, contributed to render this a profitable mode of preparing strong cokes; for the smelting of metals, and other purposes in the arts, where, with greater plenty of wood, charcoal formerly was used; and which coke, from its superior inflammability, could be used in common grates and stoves, where the draft or influx of air is insufficient to burn the common coke. On the 13th of November, 1800, Mr. David Musket of Glasgow took out a patent for various improvements in metallurgy, and, among others, for an improved coking furnace, built of fire-brick, or iron-plates, and made to exclude the external air from the coals to be coked while they are heated to incandescence, by a fire underneath with flues enveloping the coking vessel. In his specification (see *Repertory of Arts*, xiv. 182.), different constructions of these furnaces are described, some to condense the tar and soot, or lamp-black, and some for letting these escape, if their condensation should not be found advantageous. On the 18th May, 1804, Mr. Frederick Albert Winsor took out a patent for combining the saving and purifying of the inflammable gas (for producing light and heat), the ammonia, tar, and other products of pit-coal, with the manufacture of a superior kind of coke (see *Repertory*, 2d Series, v. 172.). And, lately, the same gentleman has taken out a second patent, for further improvements in these processes, but this specification not being yet filed (June 1807), we are unable here to describe minutely, and give drawings of the oven, or carbonizing furnace, as we wished to do, which he uses for preparing his patent coke, of a superior quality, as the residuum of the gas, ammoniac liquor, and oil-tar, separated in his processes (see *Gas-lights*, and *Tar-coal*), in which 300 yards in length of the wall of Carlton-House gardens, next to the Mall in St. James's Park, were, on his majesty's birth-day evening last, lighted up with gas-lamps, and burners, of various constructions, and with transparencies, and other devices, illuminated by brilliant gas-lights. This patent coke, from the experiments which we have seen, seems perfectly applicable to burning in our rooms and apartments; making a lively and pleasant fire, with a very small degree of draught up the chimney, and producing no smoke. Two pecks of coals, weighing 36 lb. coked in one of Mr. Winsor's small carbonizing furnaces, produced 24½ lb. of coke (or 67 per cent.), which, when broke into moderate sized pieces, measured three pecks. Dr. Watson obtained 58, Mr. Jars 63, and M. Hielm 73 per cent. of the weight of coals, in similar experiments.

In the smelting of ores in Silesia, it was found (1. *Bergm. Journ.* 1790. p. 320.) that 92 lb., or one measure of cokes, were equivalent to 180 lb., or three measures of charcoal; and, in another place (*ibid.* 1792. p. 60.), one measure of cokes is said to equal the effects of five measures of charcoal, or three of pit-coal.

From the experiments of M. Lavoisier, in the Stockholm Memoirs, 1781, p. 187, it appears, that the heats produced, as measured by the evaporation of equal quantities of water, under equal surfaces, and the times of consumption, to produce the same effect by four different kinds of fuel, were as follow, viz

Combustibles.	Weight.	Measure.	Duration.
Pit-coal, -	600 lbs.	- 10 cubic feet.	- 20 hours.
Cokes, -	403	- 17	- 12½
Charcoal, -	600	- 40	- 5
Oak wood.	1089	- 33	- 4.4

Whence it appears, that if coal produces a certain quantity of heat in a given time, coke, in a much smaller quantity, will produce the same effect in little more than half the time; an equal weight of charcoal in one-fourth of that time; and oak wood, of nearly double the weight of coal, in about one-fifth of that time.

The coke-ovens, mentioned in a former part of this article, began about 30 or 40 years ago, to be applied to other purposes besides the making of coke. About the year 1780, we remember to have seen a coke-oven, opening with a door almost like a large baker's oven, applied to heating the boilers of the steam-engines of the Chelsea or Pimlico water-works, but which has long since been disused. On the 23d June 1789, the right honourable Henry Seymour Conway took out a patent (see *Repertory of Arts*, iii. 75.) for improved methods of conveying and adapting the heat of coke ovens to the working of steam-engines, baking of bread, calcining and fusing of metals and ores, &c. We are told in this

specification, that three biscuit-ovens were erected and worked from the fire of one coke-oven thus constructed, the heat from it being regulated by openings and registers, with perfect success. See *OVEN*. Others of these coke-ovens were adapted for heating boilers, and for working stills.

The earl of Dundonald's method of making cokes, or cinders, after he had extracted the coal-tar from coals, for which he obtained a patent, 30th April, 1781, and the time of which was afterwards extended by act of parliament to the 1st of June 1806, required the admitting of the external air into his furnace, in sufficient quantities to carry on the combustion of the coals operated upon (see *Repertory of Arts*, i. 145.), by which the necessity of a second, or external fire, for heating the furnace was avoided; but the cokes, produced by this means, are inferior in quality to those produced in close vessels, as in the processes of Mushet, Winsor, &c. above mentioned.

Colliery

COLLIERY. Under the article **COAL** we have recently given the history of its mines and trade in Britain, its laws, the classification and description of different sorts of coal, the practice of coal-mining, and some of the principles to be observed in searching for coals; this last part admitting of farther and more general elucidation, we shall resume the subject in this place, and treat of the different opinions which naturalists have held, respecting the origin and formation of coals.

Mr. Richard Kirwan, a most indefatigable collector of facts relating to geology, when speaking of carboniferous soils or coal measures (*Geological Essay*, p. 290. &c.), states

these to be either chiefly argillaceous or arenitic, or both together, or of the trap kind, or calcareous; the circumstances of these, and of the coal found among them most worthy of notice, he states to be the following; *viz.*

1°. They commonly form distinct strata, or beds, one over the other to a great depth. The strata of coal are usually called *seams* (beds); it is very seldom found in irregular heaps (pipe-veins, bellies, nests), or veins (loads, fissures, rake-veins, &c.).

2°. These seams are scarcely ever found *single*, but those whose thickness does not exceed 14 or 15 inches, are rarely

worked. At Whitehaven five were lately worked, at Newcastle three, at Liege 20. The highest seams, and next the surface, are generally the worst (see §. 7°), but the deepest are not always the best.

3°. The thickness of different beds of coal is variable, from half an inch or less to 5 or 6 feet; but not unfrequently it amounts to 25 or 30 feet, and in some rare instances to 80 feet or more. No such seam as this last has occurred in Great Britain.

4°. Seams of coal generally occupy a considerable extent both in length and breadth, and whatever the thickness of each may be, it is commonly constant for a considerable space, as a mile or two miles; instances of a contrary kind seldom occur, unless the seam be disturbed by some obstruction (see § 16°), or at the extremities of a coal-foil, (coal-measures), or in an extent exceeding two miles.

5°. In the same stratum (seam) if exceeding 3 or 4 feet in thickness, the coal is seldom exactly of the same quality.

6°. Different seams of coal are separated from each other, by at least one, but generally by several strata of earth or stone (See article COAL); these, in a considerable extent, preserve also an uniform thickness.

7°. The uppermost seam of coal is commonly soft and dusty; it is vulgarly called *smut*.

8°. Seams of coal, and also their concomitant strata, are generally parallel to each other, unless an uncommonly thick stratum of earth, 150 or 200 feet thick, intervenes. Their number and order are also similar, to a considerable extent, yet variable in the same district and soil.

9°. In many of the concomitant strata, particularly of shale, bituminous shale, indurated clay, and sand-stone, particles of coal are found interspersed.

10°. The strata that immediately cover coal, and thence called its *roof* (crop), are shale, bituminous shale, or sand-stone; rarely any other. But they are also often found at a great distance above it.

11°. The strata on which coal reposes, and thence called its *floor*, *sole*, or *pavement*, are also sand-stone, shale, indurated clay, or semi-protolite (a reddish sand-stone or breccia). This last would, says Mr. Kirwan, in most cases, be found in its floor, if the mines were sunk deep enough to reach it. Granite has also been found in its floor in a few instances. In trap soils, trap or basalt is said to form sometimes the roof, and sometimes the sole of a seam of coal, but, in strictness, it is believed, shale mostly intervenes.

12°. Impressions of plants, particularly of the cryptogamic and culmiferous kind, are most frequently found in shale and bituminous shales that accompany coal, or which are found in coal mines, sometimes on sand stone, but very rarely on the coal itself. Roots also frequently appear in the indurated clay. Trees carbonated, or bituminated, sometimes repose on coal, or are found under it. Fluvialile (or river) shells, muscles, and land-snails, often occur; sea-shells seldom.

13°. Argillaceous iron ore is sometimes met with among the carboniferous strata of an argillaceous soil; and martial pyrites, either found, or much oftener oxygenated, and mixed with the substance of the coal.

14°. The *stretch* or *course* (drift, run) of seams of coal, and of their attendant strata, is commonly between E. and W. or N.E. and S.W. There are, however, a few exceptions to this rule.

15°. The *dip* (or pitch) of coal is exceedingly variable, sometimes nearly horizontal, sometimes from 25° to 45°, sometimes 75°, rarely approaching still more to the perpendicular.

16°. The uniform course (or plane) of seams of coal, and of the strata that accompany them, is frequently interrupted by obstructions, called *slips*, *dykes*, *troubles*, *faults*, (*hitches*,

traps, breaks, fissures, loads, knots). These never fail to elevate (rise, upcast, uptrap) or depress (sink, downcast, downtrap) the strata beyond them; or rather, the strata on each side of them are found at different heights. This observation is general, being found to hold good in every part of Britain, as well as on the continent. The inequality of the height amounts from a few inches to 120 feet, but so great an inequality is rare, and has been found only in Derbyshire. In Germany it seldom exceeds, and scarcely amounts to, 50 feet.

17°. It has been observed in Britain, that if the *slip*, &c. overhangs (hades) on one side, and consequently forms an acute angle with the seam of coal which it cuts, the continuation of the stratum will be found *lower* on the other side of the slip, and consequently, *vice versa*, if it recedes from (underlays), or forms an obtuse angle with the seam of coal on the one side; the continuation of the seam will be found higher on the other side, as in *Plate I. fig. 1. of Geology*, where *a* and *b* denote the interrupted seam of coal, and *c c*, the obstruction or *slip*, &c.

18°. These *slips*, &c. (or the matter filling them) sometimes consist of indurated clay, sometimes of sand-stone, both different from such as form the strata, but more frequently of some species of stone that never compose the strata of coal-mines, except, perhaps, rocks of the trap species; their thickness amounts in various mines, from a few inches to several yards. Nodules of coal are sometimes found in the slips, and water is frequently lodged in them. They often descend from the surface to the greatest known depths.

19°. The disposition of the strata below the surface seldom conforms to the figure of the surface. The former is often regular, when the latter is broken and uneven, and *vice versa*; very frequently the strata dip into a hill, against the rise of the surface, or cross it in a right or diagonal line.

20°. The deepest mines known are those of Namur, some of which are said to descend 2400 feet, or 400 fathoms.

21°. The seams of coal, where in contact with their *roof*; *floor*, or *slip*, have a smooth, polished, glistening surface, which shews they were originally soft.

To the above we have, in parenthesis, added several synonyms for rendering them more intelligible in different districts; we subjoin other general conclusions of this ingenious author, relative to coals, with occasional synonyms of our own, and number them in a series following the above, for the convenience of reference: *viz.*

22°. That the quantity of earthy or stony matter in the most bituminous coal, bears no proportion to the weight of that coal; bituminous coal is capable of being charred (see COKE); and then it is a substance almost entirely resembling vegetable charcoal, which, on combustion, scarcely leaves $\frac{1}{10}$ th of its weight of argil or stony matter. *Geol. Ess. p. 316.*

23°. That mines of *wood-coal* (brown-coal, Bovey-coal, sutturbrand) have no uniformity in the thickness of their seams of wood-coal (as in § 4°); on the contrary, in the most considerable of these, an uniform decrease of thickness from the place in which the wood was first heaped, is observed. *Ibid 321.*

24°. That seams of real mineral coal, and those of earth or stone that accompany them, are observed to preserve their parallelism (noticed § 8°) even after an interruption by a slip or dyke, whether elevated or depressed. But in mines of wood-coal, no such parallelism, nor even any distinct number of strata prevail, but the whole appears to be one stratum, irregularly divided by masses of clay or stone. *Ibid.*

25°. That mines of wood-coal present sudden elevations or depressions in the same stratum; mines of real mineral coal never. *Ibid 322.*

26°. That there are no slips or dykes in wood-coal mines; those of genuine coal abound in them. Ibid.

27°. That wood-coal is frequently covered with round fragments of quartz; genuine coal never. Ibid.

28°. That there is in the museum of Florence, a cellular sand-stone, the cells of which are filled with genuine mineral coal. Could this have been wood? Ibid.

29°. That genuine coal is seldom found in plains, but wood-coal frequently is, according to Voight Pract. Ibid. 323.

30°. That the impressions observed on real coal, are those of herbaceous plants, as fern, &c.; the impressions of resiniferous plants have never been discovered on the strata that accompany coal, and the trees found are commonly birch or oak. Ibid. 348.

31°. That the traces of land vegetables, and not of marine vegetables, are found on the strata that cover seams of coal, or on those on which these seams rest, or on both. Sea-shells are scarcely ever found among them, and much less the bones of fish: that, on the contrary, reeds or rushes, and fluviatile shells, have been found in the strata that cover coal. Ibid. 323.

32°. That common salt is never found in coal-mines, except when in the neighbourhood of salt springs; but on the contrary, alum and vitriol. Ibid. 324.

33°. That carbonaceous strata never present a conic elevation on both sides of a disrupted stratum, as would be the natural result of an impression from below. Ibid. 337.

34°. That coal is never to be expected in primeval mountains, as granite, gneiss, &c., but that on the sides of these, particularly if very high, or in the hanging level that slopes from them to some river or valley, it may be sought. Ibid. 347.

35°. That there is still a greater probability of finding it in the neighbourhood of mountains of argillaceous porphyry. Ibid.

36°. That it may be sought with probability of success in sand-stone mountains, if sand-stone and clay alternate, or sand-stone, clay, and argillaceous iron ore. Ibid. 348.

37°. That in any elevated land in which sand-stone and shale with vegetable impressions, or indurated clay and shale, or bituminous shale, form distinct strata, or clay, iron ore, and shale, with or without strata of sand, coal may well be expected. Ibid.

38°. That if sand-stone be found under lime-stone, or if they alternate with each other, and, particularly, if indurated clay and shale form any of the strata, they afford a probable indication of coal; otherwise coal is very rarely found in, or under lime-stone. Ibid.

39°. That coal is very seldom found with argillite, and such as has been is of the unflammable kind. Ibid.

40°. That where trap, or whin and clay alternate, and more especially trap and sand-stone, coal may be expected; it is often, but not regularly, found under basalt; wood-coal is sometimes found under both. Ibid.

41°. That coal frequently bursts out on the surface, or on the sides of hills, in a withered state, which diffuses itself to a distance from its origin, and requires an experienced miner to trace it truly to the seam to which it belongs. Ibid.

Such are the valuable observations of Mr. Kirwan, on the probable existence of coal in certain situations, and on its position and relation to the adjoining strata, &c. These observations are for the most part unexceptionably true, and will be found consistent with what we have delivered on this subject, under the article COAL; but a few of them seem to require some remarks in this place.

§ 3°. Under the names of different collieries we shall take

occasion to mention such seams of coal as are remarkable for their thickness, or other properties. The limitation of two miles, as the extent of regularity in coal seams, mentioned in § 4°, seems inconsistent with the multiplied observations of Mr. Smith and other recent observers; sometimes two or more veins of coal which are separated only by thin beds of shale, or other bituminous matter unfit for use, are found to unite, owing probably to the diffusion of the earthy matter more generally among the coal, instead of its forming distinct layers therein; but generally, in pursuing the seam further, the coals separate again; the extremities of a coal foil, can, in our opinion, only be found in the regular ending or out-crop of the measures, (see *Ending of STRATA*); or, where the strata on one side of an obstruction or fissure have been carried away by an abrasion or denudation of the elevated strata, of which we shall give some account, and mention several curious instances in England, under the term DENUDATION. We are not inclined to think, that thick intervening measures are more likely to alter the parallelism of seams of coal, as mentioned § 8°, than thin ones; the contrary opinion has probably in some cases arisen from comparing the seam on different sides of a fault or fissure, which hides or declines considerably from a vertical position. Under the article COAL, we have explained how different borings or sinkings in the same district, may differ materially, or perhaps entirely, owing to one being begun higher up on the measures or series of strata than the other, otherwise, we believe, that the same stratum will be found to have the same succession of strata under it. And here it may be necessary to note, that a place being *higher up* on the series of strata, has no relation to its actual elevation compared with the centre of the earth, or with a level line, as truly observed by Mr. Whitehurst, (*Enquiry* p. 153,) but the lowest known strata in many districts are seen on the greatest heights; this we shall amply illustrate by examples, in the progress of our work. See *Order of the STRATA*.

The semiprotolite, mentioned § 11°, certainly has no existence in a large portion of the British coal-mines, if it exists in any of them; the theory adopted by our author, of granite forming the foundation in every instance, and generally with a breccia or semiprotolite upon it, is disproved in innumerable instances by Mr. Smith's maps and sections, shewing the actual succession of strata throughout the country.

We are of opinion with M. Blumenbach (*Hanbuch der Natur. Gesch* 703), that most, if not all, of the vegetable fossil remains are *incognita*, and cannot be identified with any recent or known plants of the present race (§ 12° and 30°). The recent determinations of M. Cuvier declaring most of the osseous remains from the strata, hitherto discovered, to be *incognita*, will probably, we think, when the proper distinction is made between the regular strata fossils, and those which ought, according to our remark under the article COAL, to be considered as *gravel*, as *recent*, or as *peat* fossils, be much further extended, perhaps so far as to include every animal remain which is found actually lodged in the strata; the distinction, therefore, between *river* shells and *land* snails as accompaniments of coal, nearly to the exclusion of *sea* shells or marine remains, we consider a mere hypothesis, as we shall take future opportunities of shewing.

It is not universally true, as mentioned § 16°, that *slips*, *dykes*, &c. never fail to elevate or depress the strata, or to occasion an inequality in their levels; (see our description of dykes in the article COAL); the instances being numerous both in the coal measures and other strata, where a fissure of considerable width makes no sensible alteration in the continuity of the planes of the ruptured strata. The alterations of level which fissures occasion, are also much greater in numer-

several instances, than our author admits; besides those mentioned. (COAL), we might state on the authority of Mr. Martin, that down-casts of 40 to 100 fathoms are not uncommon in the strata of what he denominates the Mineral Basin of South Wales. (Phil. Trans. 1806. p. 242). That the dislocations of the strata (§ 17°) have been gentle and gradual, (Geol. Essays, 333), we cannot suppose, much less that the extraneous matters which fill the fissures (§ 18°) were of prior origin to the strata themselves, and occasioned the overhanging or hading of the fissures, as our author has supposed, page 334. We have reason to hope, that these and several other hitherto, unexplained phenomena of the strata, will be fully made out by the new lights which we shall be enabled to throw on the subject, arising out of the discoveries of Mr. Smith, above alluded to.

That some rare instances have occurred of the strata underneath, dipping in a contrary direction to those near the surface, § 19, must be admitted, and of which the Somersetshire coal-mines described in the Philosophical Transactions, N^o. 360 and 391, by Mr. John Stracey, seem an instance; but in general it will be found, that the plane of the strata beneath, conforms to any regular plane which is to be found on the surface, either of a hill or vale, excepting only in the first case, instances where a perfectly straight and smooth fracture of the strata has happened, and, in the latter case, where stagnant water has in times long posterior to the formation of the strata, made deposits of mud, &c. in regular horizontal layers, or nearly so. This circumstance is of the utmost consequence to be attended to in tracing the strata of a country, as also to note carefully the distinction between these original planes or facettes of a hill, and the curious curving surfaces occasioned by the ending of strata, or the less regular curving of the surface, occasioned by the fracture (generally oblique or hading) and subsequent abrasion or rounding of the top and edges of the strata by the action of most violent currents of water. The circumstance mentioned by our author, of the strata dipping into a hill, is observable at the endings of most of the strata, and on the ruptured side of a large portion of hills and mountains, where the break or fissure occasioning the hill was in the run or course of the strata, as it lies at present, which, according to the observations of Charpentier, p. 80, is very generally the case; but where the present dip is in the direction of the fissure, or is inclined in any acute angle thereto, the strata will cross the rise of the hill, direct or obliquely as the case may be.

The probability will be shewn hereafter, that some of the disturbances, or ruptures in the strata, have been confined to a certain number of the upper strata, without affecting those below, and hence regular strata may sometimes be found, under those which are broken and uneven, as mentioned in this section; and the Somersetshire coal strata above mentioned may perhaps thus be accounted for. We have never been able to discover any thing, in the upper or under surface of a seam of coal, which demonstrates its having originally been soft, as mentioned § 21°; the glistening appearance of the surface in some partings, shews only the great regularity and truth of the planes or lamina, in which the strata were at first deposited. The polished or rather rubbed surfaces of the slips or dykes in coal-mines, and indeed in the strata generally, is a circumstance which seems most surprisingly to have been overlooked by writers on this subject. Mr. Kirwan only gives it the cursory notice contained in § 21°. This rubbing seems to have arisen from violent mechanical pressure, and motion to and fro against each other, and this seems not confined to fissures or joints, where the strata are lower on one side than on the other, so as to be explicable, as the effect of the slip, or mere sinking down of one part, when

in close contact with the other; but this apparent wear in the surfaces, of even the smaller fissures, is as observable in marl and chalk pits, and all tolerably soft strata, where no alteration of the level of the strata has taken place, as where such depression of one side of the fissure is visible. See Philosophical Magazine, vol. xxv. p. 45 and 46, and vol. xxviii. p. 120. See also *Elevation of STRATA*. The facts and observations of Mr. Kirwan on coal, in sections § 23° to 25° above, agree with our remarks under the article COAL, on the unequal and apparently accidental diffusion of the wood-like substances which have formed the strata, or rather accumulations of wood-coal. That slips or dykes have never been observed in wood-coal mines, (§ 26°), can only, we think, have arisen, from the limited extent of these accumulations in the strata, at least of such as are worked; while the excavations in the planes of the strata, as well as vertically in shafts, have been incomparably greater in the proper coal districts, than in any other, and therefore it is, that the dykes &c. have there been best ascertained; and from coal-working it has been, that almost all our knowledge of the strata has been derived; they were the objects which first awakened Mr. Smith's attention to the subject of the stratification, and by observations in the next most extensive field for these observations, viz. the cutting of navigable canals, he was enabled to generalize and extend the important facts, at present so little known, but to coal-miners, within their own particular district.

Genuine coal is now very seldom worked at its out-crop, as before observed, owing to the superior quality of the same seam, when deeper covered; but wood coal is generally worked so near to the surface, as to be opened at top, or unallowed, instead of being mined for; it is no wonder therefore that gravel has been observed in contact with it, as observed § 27°.

Perhaps the specimen mentioned § 28°, did not contain genuine coal in its cells; we conjecture this, from having seen specimens of a reddish soft sand-stone, which Mr. Farey brought last summer from the foot of the cliff on the sea beach, about two miles east of Hastings in Sussex, from the vicinity of a cottage called the Grovers, which contained so many detached pieces of bitumenized wood, that were an auger-hole to be bored into it, and supplied with water, &c. something like the appearance of penetrating a coal vein, might be had in the borings; and it is this stratum, dipping under Bexhill, situate about 6½ miles to the westward, which in the opinion of Mr. F. has been there mistaken in the borings for a seam of coals, but which the improved boring apparatus of Mr. Ryan, mentioned under COAL, would have detected, and saved, perhaps, a most unparalleled waste of money, in the measures now pursuing.

The remark in § 29°, that genuine coal is seldom found in plains, is by no means true; the coal-strata about Bedworth in Warwickshire, Whibsey Slack near Bradford in Yorkshire, and numerous other places which we could mention, form extensive plains; a contrary remark to the above, would perhaps be much nearer to the truth.

It will readily be gathered, from our remarks on § 12°, that we have our doubts, on the distinctions between resiniferous and non-resiniferous plants, land and marine vegetables, and river and sea shells, as accompaniments of coal, § 30 and 31, and that we incline to the opinion, that further searches will class all or most of them among the incognita of a prior state of aquatic existence.

Impressions from below the strata § 33, especially from elastic fluids, must have formed conic elevations or craters in making their escape, and could not have produced that universal breaking of the strata which we find; which is indeed so universal, that a single acre of the surface can scarcely be

found without one, and sometimes numerous fissures through it, although the original plane of the strata is still maintained by its fragments, facts which had a material influence on the writer's reasonings upon this subject, which we have hinted at above. The seven following sections being stated, as consequences of Mr. Kirwan's particular tenets, which we shall mention presently; on the origin of coal, we shall pass them without comment for the present, and proceed to state the principal among the various opinions which have been given, on the origin of the invaluable substance, which is the subject of our present inquiry. In stating the opinions which have been held as to the origin of coal, we shall begin with that of Arduino and some others, who have supposed coal to originate from the fat and unctuousness of the numerous tribes of animals which have peopled the ocean; which matter being accumulated on the bottom of the sea, became covered by various strata, in consequence of the different changes which the surface of the earth and bottom of the seas have undergone. The most obvious objections to this hypothesis arise, from the total dissimilarity of coal to animal fat, and the levity of the latter compared with water, which should have occasioned it rather to rise to the top of the water and float, than to dispose itself in such extremely regular beds at the bottom, as to form strata of coal. The existence of a few shells in or near to coal, in some places, which resemble some of the recent sea shells, we conceive to be as far from proving it to be of marine origin (as contended by the author of this hypothesis) as the supposed resemblance of ferns, reeds, rushes, &c. and land and river shells, with the absence of bones of fish and sea salt in other places, proves it to be of land origin, § 30 and 31 of Mr. Kirwan's observations above, and *Geol. Ess.* 323.

The next opinion which we shall mention is that of M. Genfanne and others, who, from the specific gravity and hardness of some kind of coal, and its large quantity of bituminous matter, have concluded pit-coal to be a peculiar earth of the argillaceous genus, penetrated and impregnated with petroleum. To this opinion Mr. Kirwan opposes the remark in the 22^d § above, and adds, that some known species of coal, that of Kilkenny for instance, contain no petrol or other bitumen in their composition, and are thence called natural carbon. See Mr. Kirwan's *Mineralogy* ii. 49.

M. Tingry, Dr. Darwin, and others, have imagined, that heat generated by the fermentation of immense beds of vegetable matters, have distilled or separated there from the oils, naphtha, asphaltum, &c. which condensed between the strata, and have formed seams of coal, and bituminous schists. On this fanciful theory it can scarcely be necessary to comment.

Dr. Hutton imagines coal to be formed by the slow depositions of oily and bituminous matters at the bottom of the sea, which matters he supposes to have originated in the dissolution of the various animal and vegetable bodies, which are continually perishing on the surface of the earth, and in the waters of the ocean. The fuliginous matter which is separated during the combustion of various bodies on the surface of the earth, he supposes, is washed off the surfaces on which it falls by the rain, and, being thus made to flow into the rivers, is carried off by them into the sea; where it also adds, by its deposition, to the mass which is accumulating at its bottom. Another source whence he supposes this matter to be derived, is the water draining from peat mosses, which, according to his ideas, is charged with bituminous matter, very much resembling fossil-coal, when precipitated. The depositions of these matters in the sea are supposed by the Doctor to be so regular, as to produce strata, which, becoming covered by an immense weight of superincumbent earth, must thereby become exceedingly compressed and

condensed, and finally consolidated, by the powerful influence of subterranean heat; and ultimately, by the progressive change of sea into dry land, these become seams of coal, such as we now find in the bowels of the earth. Granting that oily and bituminous matters are thus conveyed by the rivers into the sea, but which Mr. Kirwan has shewn does not take place, there is a manifest absurdity in supposing these matters to sink to the bottom of the water; while it is scarcely possible to conceive, that distinct beds or strata of coal and earth, especially such regular and extended ones as we find of them, can be formed by deposition in an ocean constituted as our present one is. The operation of heat upon these coal strata has been shewn by Mr. Kirwan and others, to be inconsistent with all the circumstances attending them. It is true that sir James Hall (*Transactions of the Royal Society of Edinburgh*, vol. vii.) has endeavoured to remove the force of these objections, by shewing, in the detail of his chemical experiments, and by the specimens presented to the British Museum in June 1806, that wood, or even horn, may be converted to a substance resembling coal, by the action of an intense heat applied under a very immense pressure. Valuable and satisfactory as we think sir James's experiments to be, in proving the possibility of carbonat of lime being fused without decomposition, and of vegetable and animal substances being melted or reduced to a coal-like substance, under the heat and confinement, as well as pressure which he applied, yet we think, the difficulty of Dr. Hutton and other Plutonists to be still nearly as great as ever in shewing, that such a degree of heat ever has existed in strata, not obviously volcanic; certainly, lava, however hot we may admit it to have been, could never by its mere protrusion under beds of sea-shells, as sir James Hall endeavours to explain, in his imaginary section of a volcanic mountain and adjoining sea, (*fig. 41.* in the *Transactions*,) have heated their whole mass, in the degree which his own experiments have shewn to be necessary for the formation of lime-stone; nor is it conceivable, that the supposed superincumbent strata, much less any depth of water, could have so effectually retained the carbonic gas, as he himself has shewn to be necessary, to form lime-stone or marble out of shells or chalk; or the other gasses, so as to effect the conversion of wood and vegetables into pit coal.

The ingenious Mr. Kirwan supposes, that a large class of primeval rocks and mountains, containing carbon and petrol in their composition, have been either totally destroyed, or their heights and bulk considerably lessened by disintegration and decomposition; and that by the equable diffusion of the disintegrated particles, successively carried down by the gentle trickling of the numerous rills that flowed from those mountains, the seams of coal and their attendant strata were formed, in lakes at their feet, we suppose, but this circumstance it is difficult to gather from Mr. K's account; according to which, the decomposed felspar and hornblende formed clay, the particles of bitumen were set free, and these, when united, sunk through the moist pulpy, incoherent, argillaceous masses, and formed the seams of coal beneath them. Mr. Parkinson (*Organic Remains* I. 248.) has commented on the absurdity of such a light substance as bitumen, being supposed to descend through a pulp of argillaceous matters, and deposit itself in a stratum below it.

The next hypothesis which we have to mention, and which has numerous adherents, ascribes the formation of coal to forests of antediluvian trees, and to peat bogs, and other vegetable productions of the dry land of that period, buried during the supposed violences of the Mosaic deluge, under the strata which are found covering

them in the state of coal at this day. This hypothesis we shall examine, and state some of the objections to which it seems liable; and first, they are mines of wood-coal, described in §§. 23° to 29° above, which alone have the appearance of being formed by depositions of floating wood and other matters, in the irregularity of their extent, and the variable thickness of the seam, circumstances extremely rare in regular coal-seams, or in the matters alternating with them. Some, we are aware, have contended, that this uniformity in the thickness of regular coal seams has arisen, from the mass of deposited wood and vegetables having, since they were covered by the superincumbent strata, been liquified, or nearly so, by some process, the exact nature of which has never been agreed upon by the advocates of this hypothesis, and that in this soft state (§ 21° above) they were pressed into an uniform seam, or continued stratum. An obvious objection to this explanation, of the uniformity observed in the thickness of a real coal-seam arises from the fact, that all coal-seams present themselves at the surface in the endings of the strata, and frequently also in the sides of hills, occasioned by dislocations of the strata (§§. 19° and 41°); and here it will be difficult, if not impossible, to conceive, how the coal, when in a soft state, was prevented from squeezing out by the weight of the superincumbent strata, and forming masses of that substance at the surface, of which no traces are observable; for, the diffusion of the withered coal or smut, below the out-crop of coal seams (§ 41) has no such appearance, but in all its circumstances agrees, with the withered remains or rubble of other strata at their outcrop. We incline to the opinion, that real wood, or other recent vegetable substances, have never been found in the coal seams, or in their accompanying measures or strata: a large portion of the bituminized vegetable impressions there found certainly bear no resemblance to known woods, or plants of the present race; while most, if not all of such remains, that have been denominated after recent plants, have been so named without that care which a botanist would exercise, in classing or naming a new recent plant which was presented to him for examination. Hence the supposed resemblance to land plants, rather than to aquatic plants in these curious remains, has, as we conceive, arisen. Our next objection to the above hypothesis is founded, on the improbability of the accumulation of such immense quantities of trees and vegetable matter in the antediluvian world, in less than 17 centuries, when more than 42 centuries since have accumulated so little: if they had remained on the surface of the dry land and not decayed, a very large portion of the earth must have been thereby incumbered and rendered unfit for the habitation and use of men or animals; it is highly improbable, that they were progressively removed from the dry land to the antediluvian sea, and there preserved until the deluge. The probable quantity of growing trees and vegetables existing at the commencement of the Mosaic deluge, seems quite insufficient to account for even the British coal strata, when it is considered how much the bulk or mass of the vegetable matter has, in all probability, been reduced, by its conversion into real coal: and this last supposition is also denied us, by the Mosaic account of this event, from which (Genesis, vi. 7. 17. 19. 20; vii. 2, 3, 4. 8, 9. 14. 21, 22, 23; viii. 11. 17. 19; ix. 3. 20.) we gather, that the existing trees and vegetables (as well as fish) were not destroyed by the deluge (See DELUGE.) Some writers on the formation of coal have spoken of it, as the remains of vegetable matters, either growing in, or that were deposited in the sea, in very distant periods, and which have been immured under layers of earth, &c. by certain convulsions and de-

luges (whether the Mosaic or others, some of them have not explained) which have since occurred: insuperable difficulties will, we apprehend, be found to attend any hypothesis, which supposes the burial of the matters composing coal, at any period since the earth has been divided into sea and dry land as at present, let the origin of those matters be supposed whatever they may.

The writer of this article begs leave to state another opinion, which the recent discoveries of Mr. Smith and himself seem to render, in his judgment, most probable, on the origin of mineral coal. This writer has several times taken occasion to mention the probability, that the surface of the earth, and as far below it as concerns us at present to consider, originally consisted of parallel laminæ of different matters, not concentric to the earth, but inclined, or dipping towards the east, and ending towards the west; each succeeding lamina, in ascending the series, being generally shorter towards the west than the east, in the same manner as the very minute laminæ of crystals are now admitted to be, and thereby to form the slope, or inclination of the crystalline surface; but with these differences, that the laminæ of the earth, or the different strata were disposed to form indented or fingered endings, instead of the straight lines so generally assumed in crystals of a small size, and that the terrestrial laminæ are of very unequal thicknesses. Various circumstances, besides the immense masses of unbroken shells and other matters nearly similar to the sea shells, corals and other marine productions of the present time, shew these strata to have been deposited under quietest and probably very deep water, answering, as he conceives, to the state of the earth as described by the sacred historian, prior to the ninth verse of the first chapter of Genesis, or in the two first grand periods metaphorically called days, after which God said "Let the waters under the heavens be gathered together into one place; and let the dry land appear." Abundant evidence will, as he apprehends, be furnished by an examination of the various organic remains lodged in or between the strata, that the animals, at least those of the testaceous, crustaceous, and zoophytic kinds, whose remains they are, lived in the particular places where each is now found, at the time that the strata, on or in which they are lodged, formed the bottom of the universal ocean above-mentioned; each newly deposited stratum being a proper nidus for the production, and probably a pabulum for the nourishment of the animals peculiar to it, and which apparently in most instances ceased to exist, when new matter in process of time began to be precipitated, for the production of a new stratum upon the former one, which, also, in turn had its own peculiar animals, as their remains in such numerous instances testify.

The opinions of that able naturalist, M. Cuvier, in his recent report to the national institute of France on the transactions of that learned body in 1806, are in favour of the animal incognita of the strata, having lived where their bones are now found: and from an examination of the accounts from more than 600 places, where bones resembling those of elephants and rhinoceroses have been dug up, belonging principally to the class of *gravel fossils*, we believe, this able anatomist is of opinion, that all these differ essentially from the recent animals of these kinds and are of species now quite extinct.

Apparently, after long periods of successive deposition and animal existence, such ceased for a time altogether, or nearly; and the strata produced an immense variety and quantity of vegetables, most of them quite unlike the vegetable tribes of the present race; the immense forests

of weeds which have been discovered at the bottom of the present ocean, in some places, probably bear no proportion to the thickness and magnitudes of many of these vegetable productions of the primitive or universal ocean, as some of them probably exceeded our trees in size; their arboriferous trunks, so closely imitating wood, as not hitherto to have been distinguished therefrom; but the greater part of the vegetables appear to have been of a small size, especially on strata, which seem to have been depositing so fast as to have immured them singly, as is often the case with the bituminous or coal shales, mentioned under COAL, of which the most beautiful, various, and minute specimens, might be obtained in many coal workings. The successive depositions in these vegetable, or carboniferous soils, appear to have differed, as we have stated those of the animal, or epizootic, to do, in their fitness for producing different kinds, and a similar appearance and disappearance of different vegetable remains will be observed, in examining a series of coal measures, or strata, upwards or downwards; and, often, strata will be found intervening such, which contain no vegetable impressions, but in some rare instances, those of animals will therein be found, which observations, of too limited an extent, as we suspect, have denominated land and river exuvia, § 12° and 30° above.

It is to beds of sub-aqueous vegetables, such as have been mentioned above, uniformly and thickly covering large extensions of the planes of strata, if not their whole extent, that the writer of this article can alone look, in his view of the subject, for the true origin of vegetable coal; and according, perhaps, to the nature of these vegetables, as well as to the kind or quantity of the mineral deposits, made during their growth, will the quality of different seams of coal be found to vary, while their different thicknesses has depended, on the quantity of vegetable matter accumulated, either dead, as in our peat bogs, or then actually growing, when a deposition began to happen, either so copious or different, as to put a period to their growth, and ultimately to immure them. That vegetable impressions are rarely found in the substance of a coal-seam, as remarked by Mr. Kirwan in the passage (§ 12°) above quoted, may, we think, be perfectly accounted for, when the peculiar kind of crystallization, which all good mineral coals seem to have undergone, is taken into consideration; a change which seems to have effectually destroyed the organization of the plants composing the coal, but without a liquefaction having happened, as in some stony crystallizations, which have of

late years been noticed by mineralogists.

Mr. Parkinson endeavours to account for this change, which vegetable matters undergo in passing into coal (Organic Remains, p. 253.) by a process which he calls *bituminous FERMENTATION*, which see. According to the observations of this gentleman, fossil coal has also, in this change, had numerous septa, or thin fibres of uninflamable matter, interposed between the particles of pure bituminous matter, of which it principally consists, which has modified its inflammability in the degree which renders pit coal so well fitted for the purposes to which it is applied. In the specimens which Mr. P. examined, the inclosed particles of bitumen were in form of rhomboids, or parallelepipeds, and the separating pellicles, or septa, were formed of sulphate of lime, containing a small portion of alumine, and sometimes of sulphuret of iron also. Organ. Rem. 269.

The new opinions which we have ventured to present, if such they are, relating to the origin and formation of coal, in that and the present article, will, as we trust, be candidly received by our readers, and submitted to that sovereign test, an unprejudiced comparison with the phenomena, by which it is our sincere wish that they should either stand or fall, as it is also of the gentlemen above alluded to, through whose valuable labours and communications, we were enabled to give them.

The most remarkable colliery, or coal-work, that we have ever had in this island, was that wrought at Burrowstoness, under the sea. The veins of coal were found to continue under the bed of the sea in this place, and the colliers had the courage to work the vein *near half way over*; there being a *mote* half a mile from the shore, where was an entry that went down into the coal-pit, under the sea. This was made into a kind of round key, or mote, as they call it, built so as to keep out the sea, which flowed there twelve feet. Here the coals were laid, and a ship of that draught of water, could lay her side to the mote, and take in the coal.

This famous colliery belonged to the earl of Kinkardin's family. The fresh water which sprung from the bottom and sides of the coal pit, was always drawn out upon the shore by an engine moved by water, that drew it forty fathoms. This coal pit continued to be wrought many years to the great profit of the owners, and the wonder of all that saw it; but, at last, an unexpected high tide drowned the whole at once, and the labourers had not time to escape, but perished in it. Phil. Transf. No. 98.

Colour

COLOUR, or COLOR, from the Latin, *color*, in *Philosophy*, means that property of bodies which affects the sight only; thus the grass in the fields has a green colour, blood has a red colour, the sky generally appears of a blue colour,

and so forth; nor can those colours be distinguished by any of our other senses, besides the sight. The variety of colours, as they are presented to us by the substances that

surround us, is immense, and from them arises the admirable beauty of the works of nature in the animal, in the vegetable, and in the mineral kingdom, or, more properly speaking, in the universe. The science, which examines and explains the various properties of the colours of light and of natural bodies, and which forms a principal branch of optics, has been properly denominated *chromatics*, from the Greek word, *χρῆμα*, which signifies *colour*. We shall, however, state this theory in the present article, as being much more obviously recurred to by those persons who wish to be informed on the subject. A distinct idea of what is meant by the word *light*, may be easily formed by its contrast with darkness, which is a privation of light. With our eyes shut we have darkness; if we open our eyes, whatever we perceive through them is occasioned by the agency of light, and the various colours of bodies are parts of that light.—It has sometimes been pretended by certain ignorant persons, that they could distinguish colours by the touch; but the testimony of divers intelligent persons, who have had the misfortune of being blind, in consequence of which their touch has, from necessity, become very exquisite, has constantly contradicted those vain assertions. Besides, it will appear from the following theory of colours, that to discriminate colours by the touch is utterly impracticable. There are indeed certain pigments of common use in painting, which, either from their roughness, smoothness, unctuousity, or other quality, may affect the touch, and with a little practice a person may learn to distinguish the feel of vermilion which looks red from that of sap-green, which looks green, and so forth; but this is not the art of distinguishing colours by the touch. It is only the art of distinguishing certain peculiarities of surface. In fact if two pigments exactly of the same texture (and several such there are) but of different colour, be presented to the fingers of a man with his eyes shut, he will pronounce them to be exactly of the same colour.

The questions which naturally occur to the human mind in the contemplation of colours, are, whence do they derive their origin?—Are they produced by the coloured bodies themselves, or by something external?—Do they move from the coloured bodies to our eyes, and strike upon them, or enter them; or are they owing to some medium interposed between the various bodies of the universe?—Are they material or not?

The ideas entertained by the ancients concerning the nature of colours, were mostly wild and absurd; nor has the present theory, imperfect as it is, been formed without an innumerable variety of experiments, observations, and the concurring investigations of a great many ingenious persons. The followers of Pythagoras called colour the superficies of bodies; Plato considered it as a flame issuing from them; Zeno called it the first configuration of matter; and Aristotle said it was that which rendered bodies actually transparent. We need not add a formal refutation of those extravagant ideas, which were the mere offspring of the imagination, unsupported by experience and by reason. The philosophers of those times paid little or no regard to experiments; hence they made no discoveries or improvements worthy of being recorded. A long and unprofitable period of nearly 2000 years elapsed, from the commencement of philosophical studies in Greece, until about the time of Descartes, when the revival of learning in Europe renewed with additional vigour the enquiries concerning the nature of light and colours. And it is curious to observe by what small steps, and what circuitous ways, any useful discoveries were made. See Priestley's history of vision, light, and colours. Descartes considered colour as a modification of light, and he attributed the difference of colour to the prevalence of the

direct or rotatory direction of light. Grimaldi, Dechales, and others, supposed that a certain elastic medium of a peculiar kind filled the universe, and that the differences of colour depended upon the quick or slow vibrations of that medium. Rohault imagined that the different colours were produced by the rays of light entering the eye at different angles with respect to the optic axis. And Dr. Hook imagined that colour is caused by the sensation of the oblique or uneven pulse of light; which being capable of no more than two varieties, he concluded there could be no more than two primary colours. Such were the ideas of philosophers respecting the nature of colours, when Sir Isaac Newton began to examine the subject in his cautious experimental manner, by which means, about the year 1666, he discovered the foundation of a theory of colours, which has been justly adopted and admired by his contemporaries, as well as by the present succeeding generation.—Rays of light issuing from a luminous object, proceed in straight lines as long as they pass through a uniform medium. If they meet with a transparent medium of different density, they will also proceed through it in straight lines, provided they enter that medium in a direction perpendicular to its surface, otherwise they are caused to bend their course, so that beyond the abovementioned surface they proceed in straight lines also; but these straight lines form a certain angle with the straight lines of their direction before they entered the last medium. The bending of the rays is called the *refraction* of light, and the angle that has been just mentioned is called the angle of refraction. See REFRACTION. Newton, having presented a glass prism, or kind of wedge, to the light of the sun, which entered a dark room through a small hole, found not only that the rays were bent from their course, *viz.* refracted, but he likewise observed that the image of the sun was thereby considerably elongated; and this elongated image instead of appearing of a uniform bright white light, was resolved into a series of colours, which exactly resembled the colours of the rainbow. This elongation of the solar image thus formed, is called the dispersion of light. These colours pass from one to the other by very small, and altogether imperceptible gradations; so that it is impossible to say where one begins and the next ends. Various methods have been tried for the purpose of rendering the colours of this prismatic spectrum more limited and distinct; none, however, has been attended with complete effect. The following seems to be the best method. Let the light of the sun pass through a hole of about one-tenth of an inch in diameter, into a dark room. Place a screen at a little distance from the hole (for instance six or seven inches) within the room, and let the middlemost part of the light pass through a similar hole in the screen; the object of which is to prevent, in great measure, the scattered light or penumbra, on the sides of the spectrum. Let the light then fall perpendicularly upon a convex lens; at the distance of about 10 feet, by which means a defined image of the sun will be formed upon a screen placed at the focal distance of the lens. Now, if a prism be placed close to the lens, so that the light, after having passed through the lens, may pass through, and be refracted by, the prism; then a coloured spectrum will be formed upon the screen. The long sides of this spectrum are very well defined; but its narrow terminations are semicircular, and its whole length consists of circular coloured images of the sun intermixed with each other, especially about the middle or axis of the spectrum; yet the most predominant colours are more distinguishable from each other, especially towards the sides of the spectrum, so that their boundaries may be marked with tolerable accuracy. The glass prism fit for this experiment must be well formed,

and free from veins, scratches, bubbles, &c. Those principal colours are seven in number, *viz.* red, orange, yellow, green, blue, indigo, and violet. They do not occupy equal spaces in the spectrum; but for the proportion of their breadths, and likewise for a more accurate description of the prismatic experiments on light, see the article REFRACTION.

The above described experiment with the glass prism gave *sir* Isaac Newton reason to conclude that the white light of the sun consisted of seven colours, which had different powers of being refracted, so that the red rays were refracted less, the orange a little more, the yellow still more, and so on; hence the image of the sun was converted into an oblong variegated spectrum. In confirmation of this theory Newton instituted a variety of other experiments, which were attended with remarkable results, and the principal of them are as follows:

If the light which has been refracted and dispersed by a prism, be received again upon another prism which must be situated in a direction perpendicular to that of the former; the spectrum will by that means be removed from its original situation into a lateral one; but its breadth and its colours will remain unaltered. Now if the elongation of the beam of white solar light, and its resolution into different colours, were a modification of light produced by the prism only; then the second prism ought to expand the spectrum in breadth, so as to form a quadrilateral figure of equal sides; but instead of that we find that the colours and their breadths remain unaltered.

If the refracted and dispersed beam of solar light, be received upon a concave reflector, the different coloured rays will be reflected to a focus, where they will form a white or colourless image of the sun. But if any of the colours be stopped by the interposition of a wire, or other slender and opaque body between the prism and the reflector, then the image will become coloured with some mixture of colours. This proves that white light consists of coloured rays, intermixed in a certain proportion, and that by a mixture of the rays of the seven primary colours in that due proportion, white light is produced. Therefore, white arises from a certain mixture of colours, and blackness arises from a stoppage or absorption of all colours. This property of light and colours, may be familiarly illustrated by the following experiment: Divide the flat surface of a wheel, or the upper flat surface of a top, such as boys use, by means of lines going from the centre to the circumference, into seven parts, having the same proportion that the breadths of the colours have in the prismatic spectrum, and let those portions be pointed respectively with the seven colours. This done, if you spin the wheel or the top, so as to cause it to turn very fast, in the light of the sun; you will find that the painted surface will look white; for by the quick motion of the wheel, the impressions of the colours in the eye become mixed, and of course they form a white light. Stop the wheel and the seven colours will appear very distinct.

If, when a spectrum is formed by the light which has passed through a prism upon a screen, a small hole be made through the screen, and the rays of one colour only be permitted to pass through it on the other side of the screen; then whatever is viewed in that homogeneous light, will appear of that particular colour. Thus, if the red light only has passed through the hole, then blood, or grass, or milk, &c. viewed in that light behind the screen, will all appear red; excepting that the blood will appear of a stronger red colour than the grass or the milk. If the blue light only has been transmitted through the hole; then the above-mentioned substances will all appear blue; and the like must

be understood of the other homogeneous colours. This proves that the colours, which seem to proceed from coloured bodies in general, do not belong to those bodies; but they are the component parts of the white light, in which those bodies are viewed, and that certain bodies have the property of absorbing some of those coloured rays of the white light which falls upon them, and of reflecting others. Thus, grass reflects the green rays and absorbs the rest, hence, the green rays coming to our eyes, render the appearance of grass green; thus blood absorbs every other coloured ray excepting the red, and so forth. Black bodies absorb all the seven coloured rays, and white bodies reflect them all.

If two holes, at about a foot distance from each other, be made in the shutter of a dark room, and two prisms be used, *viz.* a prism be placed to receive the light at each hole, two spectra will thereby be formed upon the screen; and by turning the prisms gently round their axes, the spectra may be caused to fall one upon the other. Let the yellow of one spectrum fall upon the blue of the other, and at that place the mixture of those two colours will appear green. Let a small hole be made exactly at that place, and that green light will pass through the hole behind the screen, and will form a green circular image upon another screen placed to receive it. Now, if exactly behind the perforation of the first screen, you fix the refracting angle of a prism, then the image upon the second screen will not only be moved from its place, but will appear oblong, with a yellow border at one extremity, and a blue border at the other extremity; for that spot or image of the sun consists of two primitive colours of different refrangibilities. The same thing must be understood of any other colour formed from a mixture of any two primitive prismatic colours; for any two of those colours will form, or rather will look like an intermediate colour; thus, red and yellow form an orange, blue and violet form an indigo, and so forth.

If the experiment be performed with one solar spectrum: *viz.* a single prismatic colour; for instance the green be permitted to pass through a hole in the screen, and be then received upon another screen, the image will be of the same colour as in the preceding experiment, *viz.* green, and circular. Now, by placing a prism behind the perforation of the first screen, the green image will be moved from its place, but it will not be elongated nor altered in colour, because this image consists of one uniform primitive colour. (Newton's Opt. b. i. p. ii. prop. iv.) This remarkable experiment shews, that though a green may be formed from a combination, or any other prismatic colour may be formed from a combination of the two adjacent colours; yet each of those colours in the prismatic spectrum, is a primitive uniform or homogeneous colour.

Notwithstanding the conviction which naturally attends the result of the above-mentioned experiments, several persons have supposed that the primitive colours of light are not seven, but three only; namely, red, yellow, and blue; and they have been led to this supposition, by observing that the painters can produce all the other colours, by mixing either all those three colours together, or two of them, in due proportion.

A recent writer of eminence in the philosophical world, (M. C. A. Prieur) has started another theory. He thinks that the primitive colours, (*viz.* the components of white light) are three in number; but he supposes them to be the red, the green, and the violet; and that the other colours of the spectrum are formed from a mixture of those; that is the yellow from the red and the green, the blue

from the green and the violet, &c. See l'Annales de Chimie, Sept. 1806.

Hitherto we have treated of the formation of colours by refraction; from which it appears that the white solar light consists of coloured rays; that whenever that light enters a transparent medium in an oblique direction, it is caused to deviate from its rectilinear course; and at the same time its component coloured rays, are separated in consequence of their different refrangibility. The next series of facts, upon which the theory of colours depends, relates to the *inflection* of light, it having been found, that the rays of light are bent in their course, and resolved into their component colours, not only by refraction, but likewise by merely passing by the surfaces of bodies. It seems that the rays of light are attracted by bodies, when they come within a certain distance of their surfaces, and that the coloured rays of white light being attracted more or less, are separated from each other. A great variety of experiments relating to this inflection of light, were originally made by Newton, and have, since his time, been instituted by other able philosophers. But, though several remarkable facts have been discovered; yet the present state of knowledge does not admit of their being reducible to a single principle, or to any general and comprehensive laws.

In order to give our readers some idea of this property of light, we shall now subjoin an experiment related by a recent anonymous writer; referring, then, the reader to the article *Inflection of Light*, for a full account of whatever belongs to it.

"Across a beam," says the above-mentioned author, "of solar light, admitted into a dark chamber, through a small hole in a thin piece of lead, nearly $\frac{1}{80}$ of an inch wide, I interposed a hair of a man's head, and receiving the beam on a screen, or sheet of white paper at a distance, and with an obliquity convenient for the purpose, I noted the following appearances.—At the termination of what may be considered as, and therefore may be called, a shadow, whose intensity or darkness was not considerable; the following orders and distinctions of colours appeared. First, and nearest to the dark or black parts of the shadow, might be seen a diluted blue, changing into a breadth of white light, followed by breadths of yellow and red. To these succeeded an interval of diluted shade, then breadths of diluted violet, blue, diluted green, yellow, red; then green diluted yellow; red; diluted green, red; white, diluted red; and finally white light. These are the more general orders of the colours. Of these orders, the three first were sufficiently obvious and distinct; the last evanescent and requiring accommodation of circumstances to produce, and attention to perceive them." Observations concerning the Inflection of Light, &c. London 1799.

The last set of facts that remains to be mentioned, as relating to colours, consists of the phenomena exhibited by thin transparent bodies, especially by those of variable thickness. Every person must recollect to have seen the bubbles of a solution of soap, or of other thickening substance, exhibit a variety of colours similar to those of the solar spectrum, or of the rainbow. These bubbles are nothing more than thin vesicles of the solution, whose thickness varies continually. But a variety of thin solid substances exhibit the like phenomenon, such as plates of muscovy glass, or of talc; thin plates of glass; metallic and glass plates moistened with a variety of fluids, &c. Newton took two object-glasses of telescopes, one of which was a plane convex, and the other a double convex one. He laid the latter on the flat side of the other, and pressed them gently. Instantly circles of colours appeared about the

point of contact, which increased and decreased both in number and in size, according as the lenses were more or less forcibly pressed against each other. The central spot was black, and circles of colours appeared round this spot, which were brighter near it than farther off. Their order, commencing from the black spot, was blue, white, yellow, red; violet, blue, green, yellow, red; purple, blue, green, yellow, red; green, red; greenish, blue, red; greenish, blue, pale red; greenish, blue, reddish, white. (Newton's Optics, b. ii. p. 1. Observ. iv.) Experiments similar to the above have also been performed with flat glasses, lenses of various curvatures, and other substances, by other philosophers, such as Moraldi, Grimaldi, Delisle, Mairan, Mazeos, Du Tour, Muschenbroeck, &c. See an account of their experiments in "Priestley's Hist. of Vision, Light, and Colours." p. 6. sect. 6. After the above succinct account of the principal experiments that have been instituted, and the various important discoveries that have been made, concerning the nature of light and colours; it is proper to observe, that the subject is not only very far from being exhausted; but that the theory arising from those experiments and discoveries is doubtful in almost all its parts. The number of primitive colours distinct from one another, if such do really exist, is not quite determinate; the attraction between the rays of light and other bodies is an hypothesis not clearly understood; for it is a prevailing opinion with several philosophers, that the rays of light are attracted within a certain distance, and repelled beyond that distance. The reflection of coloured rays from the surfaces of bodies is likewise involved in much uncertainty; it being unknown whether the reflection takes place at the very surface, or at a little distance beyond it by some power inherent in bodies, or, lastly, from some other surface a little within the bodies, which supposition is founded upon the hypothesis that all bodies are transparent, as far as a very small part of their bulk, which hypothesis is founded upon the observation that several dense and opaque bodies, when much attenuated, become, in some measure, transparent; and such is the case with gold leaf, which, when placed against the light, appears of a greenish cast.

Notwithstanding this uncertainty respecting the theory in general, the following particulars seem to be sufficiently established; namely, that by refraction and inflection the white light of the sun is resolved into coloured light. Here it may be naturally asked whether the light of other luminous objects is not resolved, by the like means, into the same colours? The observations made in relation to this particular are not so numerous, nor so exact as might be wished; it appears, however, that some luminous objects yield rays of particular colours more abundantly than of other colours. The abbé Rochon having placed a prism before an achromatic telescope, observed through it the light of the stars; and found that the white light of Sirius was resolved into an oblong spectrum, which consisted almost entirely of three colours, *viz.* red, green, and violet. An indication of yellow was barely discernible between the two first, and a slight degradation between the two last. Through Dr. Herschell's powerful telescopes most of the fixed stars seem tinged with peculiar colours, *viz.* some evidently incline to a green, others to a red, and so forth. The light yielded by particular combustibles is also tinged with peculiar colours, and the flame of spirit of wine is a strong instance of this nature; for if common salt be mixed with the spirit, the light of its flame seems to be entirely destitute of red, yellow, and violet, and it is owing to this peculiarity that children frequently play with it in order to give a ghastly appearance to the surrounding

company. When baryt (ponderous earth) is mixed with spirit of wine, its flame is yellow; boracic acid renders it green, and strontian earth gives it a purple colour.

The phenomena of coloured bodies, as they occur to us, in general, may be distinguished into five classes, *viz.* 1st. The colours that arise from evident refraction, such as the colours of the rainbow, of the bubbles of a solution of soap, &c. 2dly. Those of opaque bodies that are fixed. 3dly. The colours of transparent bodies formed by the light passing through them. 4thly. The colours that are changeable, according to the situation of the eye, like the colours of certain silks, feathers, flowers, thin laminæ, &c.; and 5thly. Those which are changeable in consequence of a chemical alteration of the nature of the body. We shall now add a few observations respecting each of those five classes.

1. That in passing through a transparent medium, like the drops of rains, the thin pellicle of a bubble of soap, a thin lamina of talc, &c. the light should be decomposed or rather resolved into colours, is easily understood, after the above-mentioned properties of the prismatic spectrum; but the only circumstance which may require explanation is, that we perceive the colours, &c. not when the refracting body is between us and the luminous object, but when both our eyes and the luminous object are on the same side. With respect to this, it must be observed, that a transparent body, like a plate of glass, a drop of water, &c. reflects with both its surfaces at the same time that it lets part of the light pass quite through its substance. Direct your eyes to the surface of a common glass plate so as to see the reflection of an object, as in a looking glass, and if you observe attentively you will perceive two reflected images close to each other, *viz.* one from the anterior, and the other from the posterior, surface. In most looking glasses, if you place a lighted candle on one side, and view the reflected image of it from the other side, you will generally see a succession of images of the candle fainter and fainter, in proportion as they recede from the principal image. The reason of this appearance is, that since both surfaces reflect, the image formed by the reflection of the posterior surface is partly transmitted to the eye of the spectator, and partly reflected from the anterior surface to the posterior one, the latter of which is again reflected, and so on. Now, in the case of the drops of rain, when they form the rainbow, the light of the sun falling obliquely on the surface of the drop is refracted and resolved into colours, in which state it proceeds through the drop to its farther surface, from which it is partly reflected to the eyes of the spectator. The same explanation is evidently applicable to the colours of the bubbles of soap, thin transparent laminæ, and the like. See RAINBOW.

2. The fixed colours of opaque bodies are in all probability owing to their absorbing some of the coloured parts of white light and reflecting others; their immense variety arising from a mixture of the reflected primitive colours in various number and proportion; but it is impossible to say at present whether that reflection is effected at the very surface, or at some distance from it, either within or without the body; also to what cause the disposition of reflecting certain colours in preference to others may depend upon. Mr. Delaval's experiments seem to indicate that the colour of opaque bodies arises from the light that has passed through a thin layer of transparent coloured particles, and is then reflected by the smooth surface immediately under them.

3. The greatest number of accurate experiments, concerning the colours of transparent bodies, was made by

Edward H. Delaval, esq. F.R.S. (See his Paper in the Memoirs of the Lit. and Philos. Society of Manchester, vol. ii.) His experiments were performed with an immense variety of liquors differently tinged by metallic solutions, decoctions, and infusions of flowers, resins, gums, woods, mineral and animal matters. Those liquors he placed in phials of flint glass, of a parallelepiped form, with an oblong cylindrical neck. "I covered," he says, "the bottom, and three of the sides of each of these phials, with a black varnish; the cylindrical neck and the anterior side, except at its edges, were left uncovered."

In order to examine what colour those liquors would exhibit, either by transmitted or by reflected light, he viewed them through the neck of the phials, or looked into the phial through the side which had been left uncovered by the varnish. But with respect to this latter case, he says, "the uncovered side of the phial should not be placed opposite to the window, through which the light is admitted; because in that situation the light would be reflected from the farther side of the phial, and would be transmitted through the coloured liquor; and it is observable that smooth black surfaces reflect light very powerfully. Now, as it is a principal object in the experiment that no light be transmitted through the liquors, this will be accomplished by placing the uncovered side of the phial in such a direction that it may form a right angle with the window."

All the coloured liquors, which Mr. Delaval tried in the above-mentioned manner, appeared tinged with their peculiar colours, when viewed through the necks of the phials; but when he looked on that part of the liquor which filled the body of the phials, he perceived no colour whatever, the whole appearing black; which proves an important fact, namely, that transparent coloured liquors do not yield any colour by reflection, but by transmission only. "If these liquors," he observes, "are spread thin on any white ground, they appear of the same colours which they had exhibited when viewed in the necks of the phials; as the light reflected from the white ground is, in this case, transmitted through the coloured medium. But when they are spread upon a black ground they afford no colour. The black ground, however, should not be a polished body; as the light reflected thereby would be transmitted through the thin medium on its surface, and be tinged by passing through it."

Next to the above, Mr. Delaval relates various other experiments which he made with transparent solids, *viz.* with coloured glasses, which he made on purpose, by tinging the substance of the glass with metallic and other matters, in imitation of real gems. These coloured glasses exhibited phenomena similar to the coloured fluids. "Having," this author says, "formed pieces of such glasses, about two inches thick, I inclosed all their sides with black cloth, except at their farther and anterior surface. Each of these pieces of glass vividly exhibited its colour, when viewed by transmitted light: but when the transmitted light was intercepted, by covering the farther surface, the anterior surface afforded no colour, but appeared black. When plates of transparent coloured glass, somewhat thicker than window glass, are viewed by transmitted light, it is well known that they exhibit their several colours. I intercepted the light, which was transmitted through such coloured plates, by fixing a piece of black cloth contiguous to their farther surface. The plates, thus prepared, when placed in such a direction that they form a right angle with the window, appear perfectly black; which shews that the coloured particles do not reflect any light."

It is hardly necessary to observe that wherever light is transmitted through any coloured transparent body, a greater part of it is lost, than when that body is quite colourless; for by transmitting one sort of coloured rays more copiously, it stops a great part of the oppositely coloured rays.

Besides these transparent coloured bodies which have been just noticed, there is a vast gradation of others between them and those that are perfectly opaque. These, which are called semipellucid, or semitransparent, exhibit a vast variety of phenomena arising from the various proportion of the opaque and the transparent particles which enter in their composition. Thus some appear of the same colour, whether viewed by transmitted, or by reflected light, others exhibit one colour by transmitted and another by reflected light; others again appear of various colours, according to their thickness, &c. See Newton's Opt. l. i. p. ii. prop. x.

4. The last paragraph may, in some measure, tend to illustrate the nature of those coloured silks, feathers, &c. which change their colour according to the angle in which they are viewed, and in which the light falls upon them; other circumstances, however, are concerned in the phenomena of those bodies. Thus the surfaces of some of them are very irregular, in consequence of which they reflect with some of their particles, whilst they absorb most of the light with other particles; hence, when by a lateral view, the former or the latter are placed out of the direction of the eye, the colour of the whole appears different from what it does in another point of view. Certain bodies of this sort may likewise be transparent to a certain small depth, in which case they become visible partly by reflected and partly by refracted (consequently decomposed white) light; hence the eye of the spectator must, according to its situation, see some coloured rays in preference to others. The phenomena of those changeable bodies, meaning with respect to colour according to situation, are far from being clearly understood; it is most probable, however, that in them all, the three principal properties of light are concerned, namely, its reflection, refraction, and inflection.

5. In the practice of various arts, wherein colours are concerned, such as in dyeing, enamelling, painting in oil or water colours, &c. a change in colour of most of the materials is commonly observed, which is evidently produced by the action of the air, the fire, the oil, or other agent to which the colouring materials are exposed, and by which they undergo different degrees of chemical alteration in their nature. This observation, and a desire of investigating the nature of those changes, with a view of improving the practical arts dependant upon them, induced several persons to try a variety of experiments, and Mr. Delaval, the same above-mentioned gentleman, who investigated other branches of the present subject, became one of the greatest labourers in this field of inquiry. Were we acquainted with the nature of those particles in bodies which reflect or refract the coloured rays, and had we a sufficient knowledge of the alterations produced on those particles by the action of different agents or menstria, be they oils, acids, air, alkalis, &c. a just idea might perhaps be formed of the changes in colour, which must arise from certain combinations; but as the present state of knowledge does not admit the formation of such a theory, the whole must rest upon conjecture, and the practical part must depend upon the result of particular experiments.

Sir Isaac Newton thought, that bodies reflect and refract light, by the same power in different circumstances.

Also, that the forces of bodies to reflect and refract light, are very nearly proportional to the densities of the same bodies, excepting that unctuous and sulphureous bodies refract more than others of the same density. In support of this assertion he relates several experiments, the result of which he expresses in a table, wherein the proportion of the sines which measure the refractions of the several bodies, the densities of the bodies estimated by their specific gravity; and their refractive powers in respect of their densities are stated in separate columns. Mr. Delaval conceived that the denser substances ought, by their greater refractive powers, in like circumstances, to reflect the less refrangible rays; and that substances of less density, should reflect rays proportionably more refrangible, and thereby appear of several colours in the order of their density. Agreeably to this supposition he gives instances of natural bodies, which differ from each other in density, though circumstanced alike in other respects, excepting in their colour, which colour follows the order of their density; the densest being red, the next in density orange, the next to that yellow, then green, &c. In support of this hypothesis Mr. Delaval made several experiments with glass tinged by metallic particles, in which the colour of the glass, in a great measure, corresponded to the density, or to the specific gravity, of the metal concerned. But this series of experiments is not extended to that degree, nor is it conducted with that caution, which a confirmation of the hypothesis demanded. Mr. Delaval also instituted similar experiments with coloured liquors, in which he endeavoured to shew, that by an incrassation or an attenuation of their particles, their colours may be changed in one order or in the reverse. His mode of attenuating those liquors was accomplished, as he supposed, by the addition of acids, and that of incrassating, by the addition of alkalis. But however specious this hypothesis may at first sight appear, a strict examination of facts will easily shew the fallacy of it in almost all its parts, and several writers have pointed out some of its defects, but none better than Dr. Bancroft, F.R.S. in his "Experimental Researches, concerning the Philosophy of Permanent Colours," vol. i. chap. i. In this excellent work, Dr. B. shews that Mr. Delaval has not noticed the change of nature, as well as of specific gravity, which the metals undergo by their being exposed to different degrees of heat, together with the glass. He also observes, that if, according to Mr. Delaval's hypothesis, the densest bodies are of a red colour, or approximating to it, platina, the heaviest of all known metals, ought to be red; whereas it is white, like tin, and the lightest metals. Also gold, the heaviest metal next to platina, is much farther removed from the red colour than copper, which is much lighter. With respect to Mr. Delaval's experiments on coloured liquors, Dr. Bancroft says, "instead of choosing and employing mechanical means, which alone are suited to produce those effects, and only those effects, he has recourse to mere chemical agents, whose actions in the ways which he supposes must have been almost doubtful, though their powers of producing other, and very different effects from what he supposes, is most certain. Mr. Delaval, however, adopting sir Isaac Newton's supposition, that acids always attenuate, and alkalis always incrassate, prepared what he considered as a dissolving or attenuating liquor; which consisted of water with about $\frac{1}{10}$ part of *aquafortis*; and when he wanted to lessen the dissolving force of this liquor, instead of weakening it by the addition of water (which would certainly have been the most obvious and unexceptionable expedient), he chose to do it, as he says, by adding a small quantity of a solution of pot-

ash, or some other alkaline liquor, and thereby produced a new composition, the effects of which must, in many cases, prove different from those of a mere diminution of the supposed dissolving power of the former liquor. And on the other hand, when he wanted to increase the force of his acid liquor, instead of doing it by a farther addition of *aqua fortis* (obviously the most proper expedient), he recurs to an addition of *oil of vitriol*, an acid possessing very different properties, and producing very different effects, on a great variety of substances, and particularly on colouring matters; of which we could easily allege hundreds of instances, but shall content ourselves with only mentioning what is well known, that even the strongest and most concentrated oil of vitriol (used to dissolve indigo for dyeing the Saxon blue, &c.) does not destroy, or even weaken, its blue colour, though a very weak nitrous acid, or aqua fortis, will wholly destroy it, and convert the indigo to a dirty brown mass, of no use whatever." For farther observations of Dr. Bancroft on Mr. Delaval's Theory of Colours, we refer our readers to his abovementioned work. But with respect to the practical part of the subject, viz. the art of colouring glass, porcelain, &c. or the methods of forming pigments, they are requested to consult the articles, PAINTING, ENAMELLING, DYEING, STAINING, CRAYONS, and PIGMENTS.

COLOUR of the clouds, is thus accounted for by sir Isaac Newton. Concluding from a series of experiments, that the transparent parts of bodies, according to their several sizes, reflect rays of one colour, and transmit those of another, he hence observes, that when vapours are first raised, they are divided into parts, too small to cause any reflection at their surfaces, and therefore do not hinder the transparency of the air; but when they begin to coalesce, in order to form drops of rain, and constitute globules of all intermediate sizes, these globules are capable of reflecting some colours, and transmitting others, and thus form clouds of various colours, according to their sizes. Mr. Melville controverts this doctrine, in its application to the red colour of the morning and evening clouds. "Why," he says, "should the particles of the clouds become at that particular time, and never at any other, of such a magnitude as to separate these colours? And why are they rarely, if ever, seen tinged with blue and green, as well as red, orange, or yellow? Is it not more credible, that the separation of rays is made in passing through the horizontal atmosphere, and that the clouds only reflect and transmit the sun's light, as any half-transparent colourless body would do? For since the atmosphere reflects a greater quantity of blue and violet rays than of the rest, the sun's light transmitted through it ought to incline towards yellow, orange, or red; especially when it passes through a long tract of air: and thus it is found, that the sun's horizontal light is tinged with a deep orange, and even red; and the colour becomes still deeper after sun-set." Hence he concludes, that the clouds, according to their different altitudes, may assume all the variety of colours at sun-rising and setting, by barely reflecting the sun's incident light as they receive it. Edinb. Ess. vol. ii. p. 75. Priestley's Hist. of Vision, p. 446, &c.

For the distinct properties, &c. of the several colours, see BLACK, WHITE, BLUE, &c. See also RAINBOW, &c.

COLOUR, and COLOUR-Making, in Calico-Printing. The preparation of colours for calico-printing, constitutes one great branch of that beautiful art, and involves in it a series of interesting and important processes. As an art, its operations are more dependent than almost any other, on those minute differences and changes in the constitution of bodies, which it is the business of chemistry to investigate. Hence

that liability to error and uncertainty which, in the hands of the ignorant, pervades many of its processes, though conducted according to long established and approved formulae. Our present volume would scarce suffice for the various receipts in which the art abounds; yet, in the following article, we shall endeavour to lay down general principles, rather than more practical directions; convinced, that by presenting our readers with a clear and concise theory, deduced from such practical illustrations, as may be necessary for this purpose, we shall render them a more acceptable service.

The term *cola*, in calico printing, is applied not only to those vegetable, animal, and mineral solutions, which impart their own colour to the cloth on which they are applied, but also improperly to those earthy or metallic solutions, which, possessing little or no tingent properties themselves, yet retain or fix the colours of other substances, when afterwards applied to the cloth. Thus the acetite of alumine, or printers' red liquor, when pure, is almost colourless, and only becomes red by the process of dyeing, as will be explained hereafter. The acetite of iron, or iron liquor, in like manner, when used of a determinate strength, is called *black colour*, and when weaker *purple colour*, though the cloth impregnated with these solutions becomes black or purple, only as being raised, like the other, in the dye-copper.

1. The colours produced by means of these earthy or metallic solutions (which, in the language of science, are called *mordants*), form the most valuable and important series, whether considered with regard to the almost infinite variety of shades, or to their solidity and durability. These colours, from the mode in which they are produced, (the mordant being first applied to the cloth, and the colour afterwards raised by dyeing), are called *died colours*.

2. Sometimes the mordant is previously mixed with a solution of colouring matter, and in that state applied to the cloth, so as to paint or stain it, at one operation, and without the process of dyeing. Thus, another class of colours is produced, many of them possessing great brilliancy indeed, but much inferior to the former in durability. The colours called chemical, by calico printers, belong chiefly to this class.

3. In the third and last class, we may place all those, where the colouring matter is simply held in solution by an acid or alkali, and in this state applied to the cloth, without the intervention of any mordant. To one or other of the foregoing classes, may be referred all the colours used in calico printing; with the exception, however, of those systems of colours which have been produced by calico printers in this country, within a short period, by processes, and upon principles which have hitherto not been made known.

Class I.

The colours of this, as has been already observed, are produced, by first impregnating the cloth with an earthy or metallic solution, or mordant, and raising the colour afterwards by dyeing. In this article we shall confine ourselves to the preparation of the different mordants, and the enumeration of colours they afford, with different colouring substances. The operations of the dye-house, and the mode of raising the colours in the dye-copper, will be detailed hereafter.

The two great and most important mordants used in calico printing, are those that we have already noticed, viz. the solution of iron in acetous acid or vinegar, called iron liquor, and the acetous solution of alumine, or the earth of alum, called red liquor, or red colour, and sometimes yellow liquor.

With these two solutions, either separately applied, and

of various strengths, or mixed together, and in various proportions, an infinite variety of shades of colour are produced. Almost all the hues in nature may be obtained by raising them, and their various combinations with different colouring substances. From madder, with the acetite of alumine, or red liquor, we obtain various shades of red, from the darkest blood colour to a pink. From weld and quercitron bark, yellows, varying in intensity from a deep orange to a pale straw colour, according to the strength of the mordant employed. From logwood, various shades of violet; from cochineal, Brazil, and Hicaragua wood, pink and crimsons of different hues; and, in short, from almost every different colouring substance, a different shade of colour. With the acetate of iron, or iron liquor, of different strengths, we obtain from madder all the intermediate hues between black and pale purple, or lilac. From weld and bark, olives, browns, and drabs, of various hues; from sumac, logwood, galls, and other astringent substances, all the varieties of grey, from the palest shades to the deepest, in which all the minute differences of hue are lost till they approach to black. These various shades are further modified by applying two or more colouring substances to the same mordant, as madder and weld, for example, to the acetite of alumine, which produces orange, light cinnamon, nankeen, &c.; and again still further, by mixing the mordants themselves in various proportions, and raising them with either one or more of the different colouring matters. By these means shades, and varieties of colour, may be produced from a few substances only, which baffle description, and for which language has no precise or definite terms.

The acetite of iron, or iron liquor, is variously prepared. In this country it is chiefly made with the pyroligneous acid, which Fourcroy has proved to be identical with the acetous. Malt acid is preferred by many on account of its being free from volatile oil and resinous matter, with which the other abounds; but the great difference in price; and the facility with which it is obtained, has brought the acid of wood almost into general use. A series of casks filled with scraps and turnings of iron upon which the acid is poured, is almost the only apparatus necessary for making iron-liquor; yet when the consumption is great, or when it is prepared for sale, vats capable of holding several hundred gallons are substituted for casks, and the acid is kept in a state of circulation through the iron by means of pumps. The saturation is much accelerated by this motion, which prevents any deposition on the surface of the iron which might defend it from the action of the acid, and also brings fresh portions of unsaturated acid more frequently in contact with the metal. In a few weeks, sooner or later in proportion to the strength of the acid, the saturation is completed, and the liquor is then removed from the vat into casks for use, and fresh acid poured upon the iron as before. This is an easy and simple mode of making iron liquor, and as it requires but little trouble and attention, is the one most generally in use. The precautions necessary to be observed are, that the acid, if it be the pyroligneous, should not be used too soon after its preparation. It holds much essential oil and resin in solution, part of which separates on being kept a few weeks, and the clear acid may then be drawn off. It may be still further freed from resin by boiling; a portion of essential oil is thus thrown off, and the resin, if held suspended, is precipitated after standing some time. We shall have occasion to recur to this subject again, when we come to treat of the pyroligneous acid, and its formation, under the article *Distillation of Wood*. It is necessary also, that the iron should be perfectly clean and all of it malleable. Cast iron is not soluble in acetous acid. Hoop iron

cut into lengths of from eight to ten inches is preferable to any other. It is readily cleaned and more easily taken out of the vat, and returned into it again than misshapen masses sold under the name of old iron. When malt acid is employed, simple heating and washing is sufficient to free it from any foulness it may have contracted in the vat; but when the pyroligneous acid has been used, it becomes so coated with resin on its upper surface after a second or third solution, as to prolong the period of saturation to twice or thrice its usual length. In this state it must be removed from the vat and heated to redness in oven, through which there is a current of air. The resin is consumed, and the iron by heating is freed from any remains of carbonaceous matter that may adhere to it, and is again ready for the vat.

The only objection to this mode of making iron liquor is the time required to saturate the acid, which to those, whose consumption is very great, or who manufacture it for sale, is oftentimes of importance. Different processes have therefore been devised to remedy this inconvenience, in many of which the saturation is accelerated by means of heat which is applied in various ways, as best suits the convenience of the manufacturer; but the most expeditious mode is that of presenting the iron to the acid in a state of oxydation, by which means the solution is effected immediately. Calico printers have long been in the habit of using an extemporaneous acetite of iron, formed by mixing together solutions of acetite of lead and sulphate of iron. A very pure acetite of iron may be obtained by this means, but the price of acetite of lead renders this mode too expensive for general use. By forming a solution of lead, however, in pyroligneous acid and decomposing it with sulphate of iron or copperas, an iron liquor may be obtained sufficiently cheap to render this process advantageous in many cases, though still more expensive than the ordinary mode. A patent was lately taken out for making iron liquor by a process somewhat similar to this, which, however, we understand has not answered the expectation formed of it. A solution of lead in pyroligneous acid is digested on clear metallic iron. The iron becomes oxydated at the expence of the lead and is dissolved, whilst the lead is precipitated in the metallic state, and may again be used for a fresh solution. All these modes are evidently more expensive than the ordinary one of simple solution of metallic iron in pyroligneous acid, and the only consideration with the manufacturer is, whether this extra expence is counterbalanced by the economy of time or not.

The process adopted some years ago by Mr. Thomson, is perhaps the most expeditious, and next to the common mode, the most economical of any yet in use. It consists in saturating the pyroligneous acid with quicklime, and pouring the clear boiling solution on as much sulphate of iron or copperas as will precipitate the whole of the lime. A cask of iron liquor may be made by this mode in a few hours, and when care has been taken rightly to proportion the ingredients so as to produce complete decomposition, it is inferior to no solution whatever in any of its properties.

The properties of the acetous solution of iron fit it eminently above all others for the purpose of the calico printer, and having detailed its preparation we shall endeavour to point out in what this superiority consists.

The acetite of iron exists in two states, dependent on the quantity of oxygen combined with the iron. When pure, and recently prepared, it is of a pale greenish hue, but by exposure to air soon becomes tinged with brown. In this state the iron is at its lowest point of oxydation, strongly attractive of oxygen, and if precipitated by an alkali, of a deep green colour. By exposure to the atmosphere, and conse-

quent absorption of air, the solution passes to a deep red brown, and, if concentrated, deposits orange oxyd of iron, and becomes strongly acidulous. With this excess of acid, the solution now becomes permanent; the iron is almost wholly at the maximum of oxydation; and, when precipitated, of a dark red colour.

The same takes place only in a less degree, and more slowly with the sulphuric and muriatic solutions of iron. Of a pale greenish hue in their recent state, they gradually attract oxygen from the atmosphere, and become slightly red, deposit red oxyd of iron and pass to a state of acidity, at which the solution becomes permanent, and the oxydation of the iron proceeds no further.

If the solutions, properly thickened with gum or flour, are applied to cloth, the same change takes place, but with more rapidity, from their diffusion over a thin surface, and more complete exposure to the air. The aqueous and volatile part of the solution speedily evaporates, and as the oxydation goes on, the oxyd of iron is deposited on the cloth, and a portion of acid set free. When this acid is volatile, as is the case with the acetous, and also in a great degree with the muriatic, it is dissipated. The oxydation of the iron then goes on, fresh portions of acid are again liberated and drawn off till the whole of the solution is decomposed, and the oxyd of iron deposited in the cloth. When the acid is not volatile, however, as is the case with the sulphuric, the first portions of acid that are liberated not being drawn off, the oxydation proceeds more slowly till the excess of acid becomes so great as wholly to interrupt it, and great part of the iron in the operation of rinsing is again carried off the cloth. Another and more serious inconvenience attending the use of the sulphuric solution is its action on the cloth itself. The disengaged acid being in a state of great concentration acts upon its fibres, weakens, and at last destroys them. The same takes place with the muriatic solution also, for though the excess of acid is slowly dissipated, yet it has sufficient time and concentration to act very powerfully, and is, if possible, still more destructive than the sulphuric, since its action is not confined to the part on which it is applied, but from its volatility extends over the whole surface of the cloth.

It is necessary, therefore, that the acid should be not only volatile, but harmless in its action on the vegetable fibre, which conditions are more completely fulfilled by the acetous than by any other solution whatever. From the preceding observations on the properties of the acetite of iron, and the changes it undergoes on the surface of the cloth, may readily be deduced the reasons for that exposure to heat and air which calico printers have, from long experience, found necessary to goods printed with this solution. By exposure to air the iron becomes oxygenated and deposited on the cloth, whilst the heat favours the liberation of the acid, and accelerates the process. From what has gone before it may also be inferred, that the acetite of iron should be used in its recent or *green* state, since in that state the acetous acid is capable of holding a greater quantity of oxyd of iron in solution, and that consequently after its saturation and removal from the iron, it should not be too much exposed or agitated in contact with the air. On this account, also, it is wrong to pump the liquor in the vats too much when it approaches the point of saturation, since the oxygenated iron is almost all precipitated, and fresh portions immediately dissolved, so that the liquor might in time be rendered quite thick with precipitated oxyd of iron.

The preceding ideas are at variance with the general opinion respecting the state in which the acetite of iron should be employed. All the speculative writers, and even

many well acquainted with the processes of calico printing, recommend the oxygenation of the solution by exposure to air and removal from the iron, as essential to the goodness of the iron liquor. Even Berthollet, in the last edition of his "Elements of the Art of Dyeing," has fallen into the same mistake, the source of which, and the facts which seem to countenance it, we shall point out in a future article.

It is an object of importance to the calico printer to know the precise strength of his iron liquor, and to be able to ascertain this at all times, with little trouble or chance of error. Great mischief and inconvenience often arises from uncertainty in this respect, especially in the pale shades of purple, which are obtained from madder, with diluted acetite of iron. The hydrometer has been objected to, as indicating not merely the quantity of iron in a solution, but also the essential oil, resin, and mucilage which these impure solutions often contain. This objection, however, only applies where the same instrument and graduation is employed to ascertain the relative strengths of iron liquors, prepared with different acids, as the pyroligneous which contains much essential oil and resin, and malt acid which abounds in mucilage. In this case the hydrometer may indicate great differences in solutions containing equal quantities of acid and iron, but varying in the quantities of mucilage, oil, or resin. Iron liquor, however, prepared constantly by the same process, and from the same acid, varies so little in the relative proportion of its ingredients, that the hydrometer may be used to ascertain its strength in preference to any other mode whatever; provided the necessary precautions are used to correct any error arising from variation of temperature.

In a work of this kind, not illustrated by actual specimens, and without reference to some particular kind of iron liquor, it is impossible to point out the specific gravities of the different solutions required for producing the various shades, we have enumerated. An acetite of iron, of specific gravity 1.047, with madder or logwood, will produce a black, and with weld or sumac an olive, and diluted with six, eight, or ten times its bulk of water, various shades of purple, drabs, or olives, according to the colouring matter employed. A standard solution of iron once obtained, the necessary strength for producing the different varieties of colour is easily ascertained by actual experiment, and to this we must refer our readers.

When thickened with flour or gum, and tinged with a decoction of logwood or Brazil, the better to enable the workman to observe the progress and state of his work, it forms, as we have before observed, the printers black colour, a purple colour, &c. according to the strength of the solution and the purpose it is intended for. Various ingredients were formerly added to iron liquor, to improve its quality, or vary the hue of colour it produced. Verdigrise and copperas were added to the solution intended for black; and sal ammoniac or nitre to the diluted solutions for purple. These are, however, now almost universally laid aside, as being for the most part useless, and often hurtful: the simple acetite of iron being found to answer every purpose of the more complicated and heterogeneous solutions.

The *acetite of alumine*, or red liquor, is always prepared by the decomposition of alum, by an earthy or metallic salt, since the aluminous earth is not soluble in acetous acid, except in its newly precipitated and minutely divided state. The purest solution, and that which is generally used for the finest and most delicate colours, is produced by decomposing alum with Dutch sugar of lead, generally in the proportion of two parts by weight of the former, to one of the latter. The proportion of the two salts, and also the quantities of each gallon, as used by different calico printers, vary yet

with little difference in effect. The alum in general predominates so far as completely to saturate the liquor. The printers' aluminous mordant therefore is a compound solution. It is an aceto-sulphate of alumine, consisting of a saturated solution of common alum, and more or less acetite of alumine, according to the quantity of sugar of lead employed. In the neighbourhood of London, the proportions are 6lb. of alum, and 3lb. of sugar of lead to a gallon of water: when these are completely dissolved, one ounce of Spanish white is added, and the whole briskly stirred till the effervescence has in great measure subsided. In a few hours the solution becomes clear, and forms a standard liquor from which, by greater or less dilution, may be obtained all the various shades of red, yellow, &c. already enumerated. In the above formula the proportion of alum is somewhat too great, a part of it remains undissolved, or immediately recrystallizes, and falls to the bottom along with the precipitated lead. This excess of alum is however strongly insisted on by many calico printers, as essential to the purity of the mordant, from an idea that the *purest* part of the alum only is taken up in the solution. This fact however may be readily disproved by employing this undissolved or recrystallized alum in the formation of fresh solutions, whose purity will be found in no respect inferior to the former. The purity of the alum and sugar of lead, and especially their being free from iron, is of great importance in the preparation of this mordant, and on this account the Dutch sugar of lead is preferred; but its high price renders it too expensive except for the pale reds of light chintz, and other kinds of work, whose great delicacy in the red tints is required. A substitute for it has been found in the solution of litharge in vinegar, or pyroligneous acid, which is afterwards decomposed by the addition of alum, and the excess of acid neutralized by Spanish white as in the former case. Great part of the acetite of alumine manufactured and sold under the name of red liquor is prepared in this manner. It is in general used for yellows, dark shades of red, and for those compound mordants into which the acetite of iron enters, and when its purity is of course of little consequence. The acetite of lime has long been substituted with great advantage by the writer of this article for the solution of lead, and its use is becoming daily more known and extended. When carefully prepared, it is scarce inferior to the best sugar of lead, and the impure solutions answer equally with the best, for the compound mordants before mentioned. The theory of these processes is the same in all. The object being to obtain a solution of alumine or earth of alum in acetous acid. On mixing acetite of lead, and sulphate of alumine together, a change of bases takes place; the sulphuric acid unites with the lead, and falls down in the form of a white heavy precipitate, whilst the earth of alum combines with the acetous acid, and remains in solution. The same takes place with the solution of litharge in pyroligneous acid, which is indeed an impure acetite of lead, and when the acetite of lime is employed instead of lead, the sulphuric acid and lime unite and form an insoluble powder, which subsides, though less quickly than the other, whilst the acetite of alumine remains in solution above; the addition of the Spanish white is necessary to saturate a small excess of acid which exists in the solution. This excess is taken up by the lime, and immediately converted into acetite of alumine, by the decomposition of a fresh portion of alum.

The acetite of alumine when pure, is almost colourless. It has a slight acetous smell, and when boiling throws off acetous acid in great abundance, and deposits a portion of alumine. When evaporated it acquires a thick gummy con-

sistence, but does not crystallize a property which gives it a decided advantage over common alum as a mordant. It unites readily with gum, but when concentrated and holding much alum in solution, forms with flour a watery pulpy kind of paste, which has little adhesion, and from which the fluid soon separates. The sulphuric salts have indeed all a disposition to injure the thickening quality of flour.

The affinity of cotton for the earth of alum, is so strong as to separate it from its combinations even with the mineral acids. When a solution of common alum properly thickened is applied to cloth, a portion of alumine unites with it, and the acid, which held it in solution, is set free. When this is accumulated to a certain degree, it prevents any further decomposition, and in rinsing carries off the greater part of the earth again. When the acid however is volatile, like the acetous, and is dissipated as soon as disengaged, there being no longer any obstacle, the decomposition goes on till the whole of the acid is driven off, and the alumine combined with the cloth. In the infancy of calico printing, and before the theory and constitution of the different mordants was properly understood, a variety of substances were added to the solution, some of which are retained to this day. Verdigrise in the proportion of two ounces to a gallon, is recommended by many as tending to exalt the hue of yellows, and may in some cases be useful. Corrosive sublimate has been but lately laid aside, and the nitro-muriate of tin was long thought to give fixity and brilliancy to reds, when used in a small proportion with the aluminous mordant. In general, however, the aceto-sulphate of alumine is found adequate to every purpose of the calico printer; we shall not, therefore, perpetuate error by detailing any of those unmeaning mixtures which are still retained by the ignorant and prejudiced. These two mordants, the acetites of iron and alumine, and their various combinations, are those only in general use in calico-printing, for producing colour of the first class. This application is so extensive, and at the same time so simple, as to supersede the necessity of any other. The solutions of copper are sometimes used as mordants, but they afford colours of little solidity. The solutions of tin have also been employed, but we shall speak of these and other earthy and metallic solutions which have been used with partial success, when we come to treat of mordants in general.

Class II.

In this class the colours are produced by combining a solution of colouring matter with some earthy or metallic salt, capable of giving it fixity when applied to the cloth. The mordant and colouring matter are here applied at once, and the cloth is painted, as it were, or stained, with the colour it is intended to retain, and requires, in general, no farther operation than that of rinsing, to free it from the paste or gum with which it was thickened.

The colour of this class possesses, as we have before observed, in general great brilliancy, but wants that solidity and fixity which characterize the colours of the former class. The union of the mordant with the cloth is weakened by its previous combination with the colouring matter, and not being favoured by heat, as in the former case; the triple combination of vegetable fibre, mordant, and colouring matter, wants that solidity which is so necessary to constitute what is called a fast colour.

Many of these, however, are sufficiently durable to be partially introduced, and intermixed with other colours of greater durability, and some are indispensably necessary, as no better mode has yet been devised of producing them. When the

chemist's art shall have discovered means of giving fixity to colours thus topically applied, the art of calico printing will have arrived at perfection. Systems of colours may then be combined, which are at present incompatible, and the tedious operation of dyeing and bleaching, with their attendant difficulties, be banished from the art. Nor is the hope so chimerical as might at first be imagined; several of the most useful and permanent colours are of this description, as will be shewn hereafter.

We shall content ourselves with describing the leading and most useful colours of this class, giving, at the same time, the theory of their constitution. The mere enumeration of all the varieties that have or may be formed, would be endless, and foreign to our purpose.

Chemical Black.

This is the most useful colour of the class, and one of indispensable necessity in certain combinations of colours, where, for instance, it is mixed with drab, olive, and yellow, raised in the dye-copper with weld quercitron bark, or any similar colouring matter, and where the presence of any substance, such as logwood or madder, capable of producing a full black, would be ruinous to the other colours. A deep olive, approaching to black, might, indeed, be produced, by employing a strong iron liquor, as mordant, and using sumac in the dye-copper; yet as this would bear no comparison in point of intensity with the madder or logwood black, and as the force of the colouring in such course of work greatly depends on contrast, the topical or chemical black, which has all the intensity required, is almost constantly employed. The constitution of this black is pretty nearly the same in all the different formulæ in use. It consists always of a solution of iron combined with a solution of colouring matter generally of an astringent nature. On the right proportion of these two solutions, and on their due specific gravity or strength depends, in a great measure, the goodness of the black.

1. If to a decoction of Aleppo galls, in five times their weight of water, made into a paste with flour, a solution of iron in nitrous acid of specific gravity 1.25 be added, in the proportion of one measure of nitrate of iron to eighteen or twenty of the former, a black will be formed fit for almost all the purposes of calico printing, and possessing the chief requisites of this colour, namely, tolerable fixity, and a disposition to work well with the black.

2. In lieu of nitrate of iron, some calico printers employ copperas, in the proportion of one pound to a gallon of the decoction of galls. Half the copperas is directed to be dissolved in the gall-liquor before it is thickened with flour; the remaining half, dissolved by heat in as much aquafortis as will cover it, is added afterwards. This black has tolerable fixity, but does not work so well as the preceding.

3. Copperas dissolved in various proportions of from four to twelve ounces per gallon, will form, with decoction of galls or logwood, blacks of less solidity indeed than the former, yet applicable, nevertheless, in many cases where the others are not.

The constitution of the two last-mentioned blacks differs somewhat from the first. We shall point out this difference, and explain, as concisely as possible, the rationale of the foregoing processes.

When a solution of iron in nitrous acid is added to a decoction of galls, as in the first example, the solution is decomposed, the iron unites with the gallic acid and tanning principle, whilst the nitrous acid is disengaged. This is proved by the blackness which the solutions assume immediately on

being mixed. The disengaged acid, however, shortly re-acts on the new compound, the blackness gradually disappears, and in a few days, if the nitrate of iron has been added in proper quantity, the paste, instead of black, is of a dirty olive green. If the proportion of nitrate of iron be greater than $\frac{1}{18}$, this change will be effected sooner; and if so high as $\frac{1}{10}$, the paste, when applied to the cloth, will be a bright orange, like the acetite of iron. By exposure to heat and air, this colour generally deepens, becomes grey, and at last a full black. In this state it is permanent, and adheres powerfully to the cloth. These changes of colour depend on the solution of the tannate and gallate of iron in the disengaged nitrous acid, and the evaporation of the acid when exposed to heat and air on the cloth. This solution of the tannate and gallate of iron is indeed an essential requisite in the goodness of the chemical black. If the disengaged acid is not sufficient to effect this, or if it is in too great a state of dilution, the colour has but a feeble adherence to the cloth; it is not presented in a state favourable to its union with it, since the combination into which the iron has entered is insoluble in water. It lies merely on the surface, but does not penetrate its fibres, and yields readily in the various operations to which it is subjected. The chemical black, therefore, of the first example is a solution of the tannate and gallate of iron in nitrous acid.

The black of the second, but more particularly of the third example, differs from the preceding in the circumstance of the iron in the solution being in a less oxygenated state. We may consider this black in its recent state as a mixed solution of green sulphate of iron, and gallic acid, and tanning principle; for the decomposition of the sulphate is not complete till by exposure to air on the cloth the iron becomes fully oxygenated. When this black is recently applied to the cloth, it is of a pale greyish colour, has little fixity, simple rinsing in cold water being sufficient to fetch nearly the whole away. By gradually absorbing oxygen, it becomes deeper, and at last black. The sulphuric acid has no longer any action on it, and is removed in the first operation in which it is immersed in water.

The decoction of galls used for chemical black is variously prepared. Many calico printers infuse the galls cold in casks of vinegar, or pyroligneous acid, suffering them to remain several months, occasionally drawing off the lower part, and returning it on the galls. Others steep them in urine. Both these modes are vicious, particularly the last. Simple boiling in water, till all the soluble matter is extracted is sufficient, taking care to inclose the galls in a sack, that when soft they may not render the decoction thick.

Grey.

By diluting the chemical black of the first example with once, twice, thrice, &c. its bulk of water, and thickening the solution with gum, various shades of grey are obtained, which require rinsing off in water only, and the deeper shades of which have tolerable permanence.

The theory of these mixtures is the same as of the black, from whence they are derived. On the addition of water to the olive-green solution, mentioned in the preceding article, the colour instantly becomes deep purple, approaching to black. This is occasioned by the dilution of the free acid, which being no longer able to hold the tannate and gallate of iron in solution, sets part of it at liberty, which instantly regains its colour. For the reason already assigned, this has less adherence to cloth than that in which the solution is more perfect. The addition of a small quantity of nitrous acid effects this. The olive-green colour of the solution is restored,

which, by exposure to the air, and consequent evaporation of the acid, disappears, and leaves the tannate and gallate of iron more firmly fixed on the cloth. The complete precipitation of the combination is afterwards effected in the operation of rinsing off in water.

Yellow.

The false or chemical yellows are generally prepared with decoctions of French or Turkey berries, and sometimes with quercitron bark. The latter substance produces pale yellows or straw colour, but does not afford the deep bright orange yellow of the berries. Dr. Bancroft, to whom the public is indebted for the introduction and knowledge of this most useful dyeing drug; indeed, asserts the contrary in his work on "Permanent Colours;" and has given a receipt for the bark-yellow, which has, however, never succeeded in our hands.

Berry-yellow. Boil two pounds of good berries, slightly bruised, in a gallon of water during three hours, taking care to replace, from time to time, the evaporated water with liquor obtained from the second boiling of a former quantity of berries. When the liquor is cool, add to it eight ounces of alum, and if it is intended for the block thicken it with flour. If it is meant for those small objects in printed goods, which are generally touched with the pencil, two ounces of sugar of lead should be added with the alum, and the colour thickened with gum dragon. This yellow is generally passed through lime water as the first part of the operation of rinsing; by this means the greater part of the earth of alum, which would otherwise have been carried off in the operation, is precipitated on the cloth, and the colour considerably heightened.

When this operation of liming cannot be performed without injury to some other colour, a greater proportion of sugar of lead should be added. This decomposes the alum, and forms an acetite of alumine, which being more readily decomposed by the colouring matter and the cotton than sulphate of alumine, does not require the assistance of an alkaline solution to precipitate it on the cloth.

The proportion of berries above directed is for a full yellow; one fourth or one-third less will form, with the same quantities of salts, yellows of great brightness. Some calico printers add a small quantity of nitrate of copper to the yellows intended to be simply rinsed off without liming. This heightens the colour, but what is gained in intensity is lost in brightness; for if the solution of copper be added in sufficient quantity to produce any very perceptible effect, it imparts a dulness to the hue which is very detrimental. This is the invariable effect of copper in any shape, whether the acetite, sulphate, or nitrate of copper be employed.

Bark yellow. For a lemon or straw colour, it will be sufficient to make a decoction of bark by boiling from four to six pounds in as much water as is necessary during two hours, and after evaporating down the decoction to one gallon, add to it two ounces of sugar of lead, and eight ounces of alum. If not limed, the proportion of sugar of lead should be doubled. For strong yellows, Dr. Bancroft directs the addition of both nitrate of copper and nitrate of lime in quantities so great, as near seven ounces of the former to a gallon of colour. Experience, however, though it has done justice to the merits of Dr. Bancroft's discovery of the use of quercitron bark, has not verified the expectations he had formed of it as a substitute for the Turkey berries in the topical or chemical yellow.

The constitution of these colours, whether formed with

the sulphate and acetite of alumine, or with the solutions of copper is the same. Alumine, or the earth of alum, and the oxyd of copper, have an affinity both for colouring matter and vegetable fibre. They form the connecting link between these substances, which would otherwise counteract a feeble union. When a solution of alum is added to a decoction of berries or of bark, a slight precipitation takes place by the union of a portion of colouring matter with the earth; the greater part however remains suspended or held in solution by the acid of the alum. When applied to the cloth the farther decomposition of the salt is aided by the affinity of this substance for alumine, and, when the acid is volatile, as the acetous for example, by its consequent evaporation. The same takes place with the solutions of copper. The operation of rinsing farther aids the precipitation of the colouring matter and alumine, by thus largely diluting with water; and lastly, when the goods are previously passed through the lime tube, the decomposition is complete, the last portions of earth or oxyd are precipitated, and the colour thereby considerably exalted.

The solutions of tin are capable of forming very bright and beautiful yellows, with decoctions of different yellow colouring substances; but the excess of acid which these solutions necessarily contain, and their powerful action on the cloth, renders their application less general than the preceding. The solution of tin most proper for yellows is the muriatic, and is formed by digesting, in a low heat for several days, the common muriatic acid, or spirits of salt, on fine grain tin. This solution forms, with bark, a pale and lively yellow, and with berries a yellow bordering more on orange. These spirit yellows, however, as they are improperly called, are seldom used except upon dyed grounds, and of this preparation for such purposes we shall treat at large under the head of *Discharged Work*.

Blue.

The only blue belonging to this class is that produced by combining the colouring matter of logwood with the oxyd of copper. It is but seldom used since the mode of dipping China blue has become generally known; and indeed its want of durability renders it of little value. It may be produced by combining almost any of the solutions of copper with a decoction of logwood.

1. Boil two pounds of logwood in a gallon of water, and to the decoction, thickened with gum, add eight ounces of sulphate of copper.

2. To a decoction of logwood as above, add two ounces of sulphate of copper, and two ounces of verdigrise.

Their colours may either be rinsed off or limed, as best suits the style of work. The theory of these combinations is the same as the preceding.

Green.

The chemical or false green is a compound colour, and consists of a mixed decoction of logwood and berries, or bark, and a solution of copper. Though fugitive, its use is in some degree authorized by the impossibility of obtaining a green of greater durability that can be applied in figures with the block. The fast green of the calico printers is the product of two operations, and is of course limited in its application, and tedious in its use. The production of a fast green at one operation, or rather by one application to the cloth, either with the pencil, block, or press, is one of the great *desiderata* of calico printing.

1. One pound of logwood and two pound of berries boiled together during two hours, and strained whilst hot

upon two ounces of sulphate of copper, and two ounces of verdigrise, and thickened with gum, form a good and lively green, the hue of which may be varied at pleasure by the increase or diminution of the proportion of logwood. To this some calico printers add two ounces of common salt, and two ounces of sal enixon or acidulous sulphate of potash.

2. To one measure of blue of the first example in the preceding article, add two, three, four, &c. measures of a decoction of bark, made by boiling six pounds as before directed for the yellow, and to which, when reduced to one gallon, two ounces of sulphate of copper, and two ounces of verdigrise have been added. The tone of the green depending on the relative proportions of blue and yellow, it is, in general, best to keep the two decoctions separate, to be mixed, when wanted, in such proportions as may best suit the purpose required. The theory of these mixtures is the same as of the blue and yellow already described. To the eye of the mere speculative chemist, the addition of common salt and acidulous sulphate of potash in the first example, may appear unnecessary and unmeaning. They indeed affect little, either the hue or fixity of the colour, but experience has proved that this addition facilitates its working with the block, more especially when thickened with gum dragon. The cause of this, in the particular instance before us, is perhaps not very clear. The sulphuric salts in general, such as the sulphates of alumine, iron, and copper, are all unfavourable to working, as their solutions, especially when concentrated, neither thicken well with flour nor gum. A saturated solution of copperas cannot be thickened with flour, nor can a strong solution of the aceto-sulphate of alumine, in which the alum is in great excess; even with gum it unites with difficulty. But if to a solution of copperas, which refuses to form a paste with flour, a small portion of nitrate of iron be added, the whole forms a good and substantial paste that works admirably with the block; and half a pound of common salt added to the aceto-sulphate of alumine has a similar effect. In the instance more particularly before us, the addition of common salt forms a muriate of copper by the decomposition of the sulphate; but this salt is in too small a quantity to affect the working of the colour very sensibly. The cause of these effects is to be sought for in the very complicated play of affinities, which exist in such compounds, and which future investigation and discovery may perhaps unfold. The speculative philosopher, who is ignorant of the minute details of an art, that involves in it consideration and difficulties, unsuspected in the laboratory, will hence learn to suspend his judgment in deciding on the merits of a formula, till experience shall have proved the inutility of those ingredients which theory would reject as absurd.

But to return to our subject, there is a wide field open for experiment and discovery in the production of greens, into which logwood does not enter. A calico printer near London, celebrated for his ingenuity and invention in colours of this class, has long employed a green which, from its beauty and durability, when compared with the foregoing colours, indicate the presence of indigo as a constituent part. Prussian blue in a minutely divided state, and mixed with bark or berry-yellow has been employed; but the blue in this case has so little adherence to the cloth, that mere mechanical force, the operation of rinsing and washing is sufficient to disengage it. With one or other of these substances, however, it is likely that greens much superior in beauty, and probably also in durability to those ge-

nerally in use, might, by a series of patient and well conducted experiments, be readily obtained.

Pink.

The pale, and more delicate shades of red, belonging to this class, are chiefly sought after in calico printing. They are employed in giving relief or effect to other admixtures of a more sober cast, and all the skill of the colour-maker is exerted in giving them brilliancy and richness of tint. They are chiefly produced from decoctions of Brazil, nicaragua, or peachwood, and cochineal, raised and fixed on the cloth with solutions of tin, rarely with the aluminous mordants, though delicate and lively colours may be produced this way.

The nitro-muriate of tin is chiefly employed, though the relative proportion of the two acids, and their degree of saturation with tin, varies almost with every calico printer. The solution itself, made according to established rule, and with the same properties, varies so considerably at different times, as wholly to alter the nature of its compounds, without any apparent cause of failure. The source of this discordance is to be sought for in the constitution of the solution itself, which, from causes that we shall endeavour to explain, is subject to considerable variation.

First, from the strength or concentration of the acids employed, which are seldom uniform or constant; muriatic acid from the same manufacturer varying often in specific gravity from 1.12 to 1.18, and nitrous acid not less than from 1.15 to 1.23, without reference to the common distinction of single and double aquafortis.

When the specific gravity of the acids is neglected, as is but too generally the case, these differences occasion serious inconveniences in the use of solutions, whose properties often depend on the accuracy of their proportions, and on determinate degrees of saturation.

Secondly, from the impurity of the acids. The muriatic acid of commerce always contains iron and sulphuric acid; if the former exist in any notable proportion, it is unfit for the solution of tin; the presence of the latter is of less importance, though, on the whole, unfavourable to delicate colours. The nitrous acid varies considerably in its purity, being subject to greater or less admixture with the muriatic; the nitre it is made from being seldom free from marine salt. The aquafortis of commerce is, in fact, an aqua regia. This variation of the proportion of muriatic acid in the nitrous, is of the utmost importance, since the properties of the solution eminently depend upon this. With muriatic acid only, tin forms a colourless and permanent solution, one of whose distinguishing properties is, its strong affinity or attraction for oxygen. With decoction of cochineal, it forms a deep and dull purple-coloured precipitate, which, however, gradually absorbs oxygen, and becomes crimson, especially when exposed on the nitre. With decoctions of Brazil and peachwood, it affords crimson precipitates, varying in intensity with their saturation with tin. It decomposes all the combinations of iron with colouring matter, deoxygenating the iron which it carries off, leaving the tin in combination with the colouring matter. Thus a madder black becomes a red on the application of muriate of tin. On this property is founded the art of printing on dyed grounds, of which we shall treat hereafter. With nitrous acid, unless very dilute, tin contracts a very feeble union, and is generally precipitated as soon as dissolved, in a state fully saturated with oxygen. The addition of a small quantity of muriatic acid renders this solution more permanent, provided it be not fully saturated with tin, and the addition

of larger portions approximates the solution still more to the nature of the former, and renders it capable of supporting a greater degree of saturation. The properties of the solution depend greatly on the proportion of muriatic acid, and consequently of muriate of tin contained in it. When small, the precipitate with cochineal is bright carmine scarlet. It does not decompose the combinations of iron with colouring matter, unless the solution be far from saturation, and this effect is then due to the disengaged acid only.

The purity of the tin is another requisite which should be carefully attended to. The fine tin of Cornwall, commonly called grain tin, should be employed. If alloyed with lead, it is wholly unfit for these purposes.

In lieu of muriatic acid, sal ammoniac and common salt are oftentimes employed to form an aqua regia with nitrous acid. The solution differs little from that formed by a mixture of the two acids, the allowance being made by the portion neutralized by the alkali of the neutral salt.

From this short outline of the history of the substances employed in the formation of the solutions of tin, and of the properties of the solutions themselves, may be deduced such general ideas as will elucidate and explain many anomalous effects in their combinations with different colouring matters, and seem to direct future experiment in the discovery of those minute, but often important, conditions necessary to the formation of particular shades of colour.

The following examples of spirit reds, as they are improperly called by calico printers, will illustrate some of the preceding observations, and may be considered as specimens of the most beautiful and brilliant colours it is possible to form upon cotton.

1. Prepare an aqua regia by dissolving two oz. of sal ammoniac in one pound of nitrous acid of specific gravity 1.25. To this add two ounces of fine grain tin; decant it carefully off the sediment, and dilute it with $\frac{1}{4}$ its weight of pure or distilled water.

To one gallon of water add one pound of cochineal, ground as fine as flour; boil half an hour; then add two ounces of finely pulverized gum dragon, and two ounces of cream of tartar, and stir till the whole is dissolved. When the liquor is cool, add one measure of the preceding solution of tin, to two of the cochineal liquor, and incorporate well by stirring. Apply this with the pencil or block, suffer it to remain in the cloth six or eight hours, then rinse off in spring water. This colour will be a bright and beautiful scarlet.

2. Boil 12 pounds of Brazil chips during an hour in as much water as will cover them. Draw off the decoction, and pour on fresh water, and boil as before. Add the two liquors together, and evaporate slowly down to one gallon. To the decoction whilst warm add four ounces of sal ammoniac, and as much gum dragon or senegal as will thicken it for the work required. When cool, add one of the solution of tin before described, to four, six, or eight of the Brazil liquor, according to the colour wanted. Suffer it to remain from 18 to 24 hours on the cloth, then rinse off in spring water as before. The colour will be a pale and delicate pink. If it is required deeper, the decoction must be made stronger, and used in the proportion of three or four to one of the solution of tin. Nicaragua or peachwood, though not so rich in colouring matter as Brazil, yields a colour, however, which is, if possible, more delicate and beautiful. The fine pinks produced by certain houses, which have for years been the envy and admiration of the trade, are afforded by this fine dye-wood.

These colours require no liming, simple affusion with water being sufficient to precipitate the colouring matter in combination with the tin. The theory of these mixtures is the same as the preceding. They require, however, a greater excess of acid to hold the colouring matter in solution. A decoction of cochineal poured into a saturated solution of tin, occasions an instant precipitate which is not redissolved, and the greater part of which, if applied to cloth, would come off in the operation of rinsing. It is sometimes necessary to add a small quantity of muriatic acid to prevent this precipitation, or to correct it when it happens, and sal ammoniac is supposed to have the same effect, probably by engaging the water of the solution.

With the aluminous salts, the decoction of cochineal and Brazil forms colours less brilliant than those we have just described, but which are applicable in cases where the excess of acid in the solutions of tin is attended with inconvenience.

1. To one gallon of water, add eight ounces of finely ground cochineal, and two ounces of bruised galls; boil half an hour, strain the liquor whilst hot through a fine cloth, upon four ounces of cream of tartar and four ounces of gum, and thicken with gum dragon. This colour requires liming.

2. Upon 6lbs. of Brazil and 2 oz. of galls, pour one gallon of water, let them soak some time, then boil two hours, replacing the evaporated liquor with fresh water. Strain through a fine cloth upon 4lb. of gum senegal, and add one pint of the acetite of alumine, described in a former part of this article.

The addition of galls in the two preceding formulæ is supposed to impart solidity to the colours in some way analogous to the operation of galling in silk and cotton dyeing, of which we shall have occasion to speak hereafter. Their constitution is otherwise the same as the berry and bark yellows, and most others of this class of colours.

Purple.

1. If the solution of tin directed for the pink in the last article be mixed with six times its bulk of a decoction of logwood poured whilst hot upon four ounces of sal ammoniac, and $2\frac{1}{2}$ lbs. gum senegal, a bright and lively purple will be obtained, the hue of which varies with the strength of the decoction and the proportion of solution of tin employed.

2. If instead of the solution of tin, the acetite of alumine before alluded to, be used in various proportions of one sixth, eighth, &c. purples differing in shade and intensity will be formed, applicable in some cases, but possessing less solidity than most of the colours already described.

The constitution of these compounds is the same as the preceding.

Olive.

Olives are variously compounded, according to the colour required.

1. By mixing chemical black in various proportions with berry or bark yellow. The depth and fulness of the olive depends on the quantity of black.

By a decoction of logwood added in greater or less quantity to the bark or berry yellow.

3. By the addition of copperas or nitrate of iron to decoctions of yellow or astringent colouring matters, such as bark, sumac berries, weld, &c. each of these produces a different hue, varying from the green olive to a drab or cloth colour. By mixing these decoctions in different proportions, and by varying their strength, and the quantities of copperas

or nitrate of iron added to each, a multiplicity of shades may be produced, of which it is impossible to convey any precise or definite ideas.

These colours may be indifferently thickened with flour or gum, as best suits the work required, but when nitrate of iron is added to solutions containing gum, the instant coagulation that takes place must be counteracted by the addition of a portion of free nitrous acid. This effect arises from the strong action exerted by metallic oxys, at the maximum of oxydation, on mucilage or gum. When the decoction is very concentrated, and contains sufficient colouring matter to engage the whole of the iron, this effect takes place in a less degree, but with solutions adapted to the production of the foregoing colours, a coagulation invariably takes place, unless counteracted by the presence of a portion of free acid. Of this action of metallic oxys on the solution of gum we shall further treat under the article GUM.

Class III.

In this class, the colouring matter is simply held in solutions, by an acid or alkali, and in that state applied to the cloth without the intervention of any mordant.

The most important of these colours, is the alkaline solution of indigo which forms the topical or.

Pencil Blue.

1. Prepared solution of pot-ash, by boiling together $7\frac{1}{2}$ lbs. of quick lime, and 15 lbs. of pot-ash, in 10 gallons of water. Decant off the clear liquor, and separate the remainder from the lime by means of the filter. To one gallon of this solution, add 1 lb. of red arsenic, or orpiment, and 1 lb. of fine indigo, both previously ground together in a mill with sufficient water to form a thick paste. Bring them up gradually to a boil, stirring carefully all the time, and then withdraw the fire. Thicken the solution with the best gum fenegal, and for the pale shades of blue, dilute with one, two, &c. measures of gum-water.

The quantities and relative proportions of pot-ash, orpiment, and indigo in a gallon of pencil blue vary considerably with different calico printers, and within certain limits, it appears, that the accuracy of these proportions is not of great importance. Hausman, an intelligent French printer, employs 15 lbs. of pot-ash, 6 lbs. of orpiment, and 8 lbs. of indigo, to 12 gallons of water; and Oberkamp, proprietor of the celebrated manufactory of Tony, a still greater proportion of indigo. Some printers add brown sugar, and Bancroft has proposed to substitute this for the orpiment, but without success.

The solution, when recently made, is a yellowish green, but by exposure to air, becomes gradually deeper, and at last blue. In this state, it is wholly unfit for use, it contracts no union with the cloth, and is detached from it in the first operation of rinsing.

Of the peculiar nature and properties of indigo, we shall have occasion to treat hereafter, under its proper head, at present it will suffice to observe, that it owes its colour and insolubility in alkalies, to a portion of oxygen intimately combined with it. To render it soluble, therefore, it must be deprived of this oxygen, by the action of a substance having a more powerful affinity for it, and the sulphuret of arsenic, or orpiment, is used for this purpose. Sulphate of iron, has a strong affinity for oxygen, and is employed in de-oxygenating indigo for certain purposes; but the oxyd of iron not being soluble in alkalies, the solutions of indigo, formed by it, become quickly regenerated by the absorption of oxygen, and cannot even be transferred from one vessel

to another. The sulphuret of arsenic, on the contrary being very soluble in alkalies, presents the double advantage of de-oxygenating the indigo, and of retaining it awhile in that state, till on its application to cloth, it becomes exposed so completely to the action of atmospheric air, as to regain its oxygen, colour, and insolubility; and becomes fixed in its original or blue state.

The copper coloured pellicles, which forms on the surface of pencil blue, and is renewed immediately on its removal, arises from the absorption of oxygen, which, in spite of the action of the orpiment, is continually taking place. Hence arises that disposition to unevenness, which is the great disadvantage of this blue; the unavoidable exposure to air of small portions of the colour during its application with the pencil, reviving greater or less portions of indigo, and considerably reducing its strength.

Molt calico printers boil up the quicklime with the other ingredients, thinking its presence not less necessary than the pot-ash and orpiment; by this means a considerable portion of the solution of indigo is taken up by the sediment, which careful washing does not wholly separate. As the action of the lime is confined merely to the alkali, which it renders caustic, and capable of acting with greater force on the other ingredients; it is certainly much more economical to render the pot-ash caustic before its addition to the indigo. A considerable waste of colour is by this means prevented, and the solution may be thickened the moment the ebullition has ceased without waiting for the deposition, which in the old mode takes place.

Orange.

The oxyd of iron, when dissolved in acetous acid, forms one of the most useful and important mordants, as we have already shewn in the former part of this article. It is also capable of imparting a very pleasing and permanent colour itself to cotton, when applied in solutions of tolerable strength and purity, and forms the orange, buff, and gold colour of the calico printers.

1. The solutions of iron in vinegar, strengthened by the addition of copperas may be used, but the purest and brightest gold colours are obtained from copperas and sugar of lead, in the proportion of 5 lbs. of the former, and 1 lb. of the latter, to a gallon of water. When thickened with gum, and employed undiluted, it affords, when lined, a full strong gold colour, and with two, four, six, &c. times its bulk of water, various shades of orange and buff, which resist the action of air, alkalis, and soap; and are rather exalted than impaired by frequent washing. The addition of sugar of lead, is to increase the strength of the solution. A gallon of water dissolves about 4 lbs. of copperas. The addition of a pound of sugar of lead, enables it to take up another pound nearly, and the strength of the solution may be still further increased by equal additions of the two salts. The operation of liming is a simple precipitation of the oxyd of iron on the cloth, and in cases when this cannot be performed, the proportion of sugar of lead must be increased to nearly that of the copperas. It is only the paler shades of orange, however, which are to be obtained this way. The deep gold colour before named, is not to be procured without the aid of a precipitant. Spanish brown is sometimes added to a solution of iron, and employed in such a case, but it contracts no union with the cloth, and is readily removed by simple washing and beating. When the orange, or gold colour, is thickened with flour, a small portion of nitrate of iron must be added to the paste, for reasons we have assigned on a former occasion.

2. A beautiful, but fugitive orange, is obtained by boil-

ing half a pound of annotta with 1lb. of caustic pot-ash in a gallon of water, and thickening the liquor with gum. This colour acts powerfully on the sleeves and blocks, which it very soon destroys, and on this account, and also from its want of permanence is seldom used. It may either be simply rinsed off, or first passed through water rendered slightly acidulous with sulphuric acid, or what is still better through alum-water. This operation is the very reverse of liming, for here the colouring matter to be precipitated, being held in solution by an alkali, an acid must be employed for that purpose. The colour by this means is considerably heightened, and when applied with the pencil, is useful in some cases where the other colours will support the action of alum-water without injury.

Borax, and even spirits of wine, are sometimes added to the alkaline solution of annotta, and are supposed to contribute to its strength and fixity, though on what principle it is not easy to discover.

Green.

The oxyd of copper, dissolved in volatile alkali, affords a pale and delicate green, which is sometimes employed intermixed with other colours. Turnings of copper, or verdigrise, which is more generally used, may be digested in a low heat with spirits of sal-ammoniac. Care must be taken that the heat be very moderate, and the vessel in which the solution is made, well stopped, the ammoniac will otherwise be driven off, and lost. When the alkali has taken up as much copper as it can dissolve, the solution must be thickened with gum, and applied with the block or pencil. In a few days the ammoniac evaporates and leaves the oxyd of copper on the cloth, which must be rinsed to free it from the gum and superfluous colour.

The blues produced by alternate immersion in copperas and lime, and also in the solution of indigo, by the same substances, properly come under this class of colour, as they are solutions of colouring matter in lime and alkalis. As the processes by which they are applied, differ however very materially from all those that we have been treating of, they claim a separate and distinct notice. For the details of these operations, and the mode of preparing the pastes for bark and pale blue dipping, and the colours for China blue, we must therefore refer our readers to the article *Dipping Blue*.

COLOURS, in Dyeing.—There are five simple, primary, or mother colours, used by the dyers: from the mixture whereof all the other colours are formed; these are blue, red, yellow, black, and brown colour; each of which see under their proper head, **BLUE, RED, &c.**

Of these colours, mixed and combined, other colours are formed, which are infinitely various, according to the proportion of the different ingredients that are employed, or the processes by which they are blended. Thus a mixture of blue and yellow forms green, which is distinguished by dyers into a variety of shades, according to the depth of the shade, or the prevalence of either of the component parts. Hence we have *sea-green, grass-green, pea-green, &c. &c.* Blue and red form different shades of violet, purple, and lilac. A mixture of yellow and red produces orange. Mixtures of black with other colours constitute greys, drabs, and browns. For a more particular account of these and other colours; and the method of procuring and applying them; see the article **DYEING**. See also the preceding article.

The greatest perfection in the art of colours would be to find the means of preparing the finest colours without the use either of acid or alkaline salts, which usually subject the colours to change, or else are apt to prey upon the

cloth, canvas, &c. as we see in verdigrise, the blue and green crystals of copper, &c. It appears highly probable, that the Indians, for making the fine bright and durable colours, wherewith their chintzes and callicos are stained, make use of metalline solutions; for some stained callicos, brought from thence, having been kept 40 or 50 years, the bright colours have been observed to eat out the cloth, exactly in the same manner as acid spirits, which dissolve metals, are found to do.

Since these, then, are the inconveniences attending such colours, we ought to search for menstrua with which to extract colours, which are neither acid nor alkaline; and for such metalline oxyds, precipitates, or powders, as will not lose their colours, by being well washed to get out their salts; to prepare certain metalline matters, by mere calcination, or the bare assistance of fire; and lastly, to look out for native colours, wherein no saline matter abounds.

Mr. Geoffroy has given a very curious process for making two clear, spirituous, inflammable liquors, which differ very little in taste and smell, and being mixt together give a fine carnation colour, without any sensible fermentation.

To make the first of these liquors, put a small handful of dried red roses into a glass bottle; pour on them rectified spirit of wine, till it covers them an inch; let this stand in a cold infusion four or five hours; then pour off the liquor, which will be clear and colourless, as when put on. The second liquor is made by dropping into rectified spirit of wine, so much oil of sulphur, by the bell, or spirit of vitriol, as will be borne in it without giving it any very sensible acidity when tasted. When these liquors are thus prepared, let a small quantity of the latter be dropped into some of the former, and the whole will become of a fine carnation colour, though there is no fermentation, nor any other change perceived in it, but barely that of colour. If instead of this last liquor, there be added to the first a few drops of the spirit of sal ammoniac, the whole will become green.

Make a slight infusion of galls in water, so as not to colour the water; make also a weak solution of green vitriol in water, so that it may appear colourless; mix these two colourless liquors together, and an inky blackness is immediately produced; add to this black liquor a little oil of vitriol, and the liquor becomes pellucid and colourless again; then add to this a little salt of tartar, and the whole is black again.

Put a little bruised camphor into rectified clear oil of vitriol; shake the mixture, and it will become black, and the camphor will be dissolved; add to this a little water, and the liquor becomes clear, and the camphor is found separated at top, in its own form, and native whiteness.

Infuse lignum nephriticum in cold water, and pour off the clear liquor. This held up against the light, appears of a fine yellow, but viewed from the light, of a beautiful blue: a little spirit of nitre put to this liquor makes it lose the power of reflecting the blue rays, and a little oil of tartar, afterwards added, recovers that power again.

Logwood, infused in water, gives a red colour. Put to this a little spirit of urine, and it becomes of a fine purple; and drop in afterwards a little spirit of salt, and it becomes of a pale red.

A beautiful blue tincture may be made from filings of copper, by digesting them in spirit of urine, hartshorn, or the like. The addition of oil of vitriol destroys the blue colour; and a little spirit of salt turns it green.

Pellucid oil of vitriol, mixed with pellucid oil of turpentine, produces a thick red balsam. And common oil, mixed with fair water, by means of a little wax, and continued

COLOUR

rubbing, turns into a thick white balsam, called cold cream.

Oil of vitriol, distilled from quicksilver, leaves a white powder behind, which, if water be poured on it, becomes yellow.

Dissolve quicksilver in spirit of nitre, and to part of it add spirit of urine, and a white powder is precipitated; to another part of the solution add oil of tartar, and a yellow powder falls to the bottom.

Dip a new pen in spirit of vitriol, and write with it on common blue paper, and the letters will appear red.

A pellucid solution of saccharum saturni being written with on paper, becomes invisible when dried; but the bare fumes of an infusion of quick lime, and orpiment, in water, will render the invisible writing black and legible.

Volatile salt of sal ammoniac, which is white, mixed with crystals of copper, which are green, produce a fine purple.

The original and simple, as well as the mixt, colours are producible by mixture. Thus, if the sun's rays pass through two pieces of glass, the one blue, and the other yellow, and be afterwards received upon a white paper, the

colour there seen is green. The dyers make cloth blue with woad, and then turn it green by the yellow herb called luteola, or dyers' weed. To a yellow solution of gold in aqua regia add a blue one of copper in spirit of urine, and the mixture becomes green. The painters every day practise this art of producing new colours by mixture.

Metalline and mineral matters are reducible to a considerable degree of subtlety, or smallness of parts by fire, or dry calcination, so as to leave them durably possessed of their native or adventitious colours. Thus lapis lazuli, by being calcined, becomes the fine, rich blue called ultramarine; light ochre, by the same treatment, becomes a light red, or flesh colour, the most useful flesh-colour in painting. Lead, by calcination, becomes durably red, and iron durably brown; but a proper method seems wanting for the dry calcinations of the nobler metals, gold and silver; though, for the uses of gilding, these are easily prepared by dipping linen rags in their respective solutions, and then drying, and burning them to ashes, whereby a dry and fine metalline powder is procured.

Comb Making

Comb making. Combs are not only made for the purpose of cleaning the hair, but for ornament: they are sometimes set with brilliant stones, pearls, and even diamonds; some again are studded with cut steel; these are of different shapes, and are used to fasten up the hair when ladies dress without caps. Combs may of course be had of all prices, from the value of a few pence to almost any sum. They are generally made of the horns of bullocks or of elephants, and sea-horses teeth, and some are made of tortoise-shell and ivory, others of box or holly-wood. The horns of bullocks are thus prepared for this manufactory: the tips are first sawn off; they are then held in the flame of a wood fire, this is called roasting, by which they become nearly as soft as leather. While in that state they are slit open on one side, and pressed in a machine between two iron plates; they are then plunged into a trough of water, from which they come out hard and flat; they are then sawn into lengths, according to the size wanted. To cut the teeth, each piece is fixed into a tool called a claw. The maker sits on a triangular sort of a stool to his work, and under him is placed the claw that holds the horn, ivory, &c. that is to be formed into a comb. The teeth are cut with a fine saw, or rather a pair of saws, and they are finished with a file. A coarser file, called a rasp, is used to reduce the horn, &c. to a proper thickness; and when they are completely made, they are polished with charcoal and water, and receive their last finish with powder of rotten stone. The process used for making ivory combs is nearly the same as that already described, except that the ivory is first sawed into thin slices. The best ivory comes from the island of Ceylon and Achen in the East Indies, as it possesses the property of never turning yellow; it is consequently much dearer than any other kind.

Tortoise-shell combs are much esteemed; and there are methods of staining horn, so as to imitate it, of which the following is one: the horn to be dyed is first to be pressed into a flat form, and then done over with a paste, made of two parts of quick-lime and one of litharge, brought into a proper consistence with soap-ley. This paste must be put over all the parts of the horn, except such as are proper to be left transparent, to give it a nearer resemblance to tortoise-shell. The horn must remain in this state till the paste be quite dry, when it is to be brushed off. It requires taste and judgment so to dispose the paste, as to form a variety of transparent parts, of different magnitudes and figures, to look like nature. Some parts should also be semi-transparent, which may be effected by mixing whiting with a part of the paste. By this means spots of a reddish brown will be produced, so as greatly to increase the beauty of the work. Horn thus dyed is manufactured into combs, and these are frequently sold for real tortoise-shell. The wages of journeymen in this business are from 21s. to 31s. per week.

In *Plate XV. of Mechanics* is represented a machine for cutting combs, for which Mr. William Bundy, of Pratt Place Camden Town, took out a patent in the year 1796, and the same is described in the *Repertory of Arts*. The frame *A A*, *fig. 3* of the machine, is like a common lathe, containing a spindle, with a crank and fly-wheel, *D*, upon it, turned by the alternate motion of the treadle, *B*, which is moved by the workman's foot; *E* is a wheel fixed on the crank spindle, carrying a line in its groove, crossing between the cheeks of the lathe, and passing over the pulley, *F*, which turns on a centre fixed in the puppet, *G*; it has two holes in it to receive the horned catch, *a*, *fig. 2*, screwed on the end of an arbor, *b*, about seven inches in length, and half an

inch in diameter; this arbor is mounted between two circular brass plates, *H*, *I*, *fig. 1*, connected by three pillars, it carries as many circular steel cutters, or saws, *K*, *fig. 4*, as the comb to be cut is to have teeth. *M*, *fig. 5*, represents another arbor, which is fixed in the frame-plates, *fig. 1*, by its ends; it is triangular, and has a piece of steel, *L*, *fig. 4* (called a guide), fitted on it between each saw, on the arbor, *b*. These parts are put together by first putting the end of the arbor, *b*, *fig. 2*, through the hole in the centre of the frame-plate, *I*, and screwing on the catch, *a*; the end of the arbor, *fig. 5*, is put into a square hole made in the plate, *I*, to receive it, and is fixed by a screw; a guide, *L*, *fig. 4*, is then put on the arbor, *M*, close against the shoulder, *d*; next a cutter, *K*, is put on the arbor, *b*, touching its shoulder, *e*; a piece of steel plate, *N*, called a guide-washer, is then put on the arbor, *M*, and another guide, *L*, close to it; the guide-washer is a little thicker than the cutter opposite it, so that the cutters each turn between two guides without touching them. These being in their places, a small washer, *O*, *fig. 4*, is put on the arbor, *b*, and a cutter, then a guide-washer and guide, on the arbor, *M*, and so on alternately, till the right number of cutters are put on; the sliding shoulder, *f*, *fig. 2*, is then taken, and with the octagonal nut, *g*, screwed tight up against the last cutter, put on the arbor, *b*, this will pinch all the cutters and washers between the shoulders, *e* and *f*, and hold them fast. The same is done to the arbor of the guides, and, lastly, the frame-plate, *H*, is put on the ends of the pillars, and screwed fast; the whole forming the resemblance shewn in *fig. 1*. The frame plates with the arbors, as in *fig. 1*, are now to be put in their place in the machine, *fig. 3*, the horns of the catch, *a*, going into two holes in the pulley, *F*, and the other end of the arbor, *b*, into a centre that goes up with a screw in the puppet, *Q*; the screws, *b*, *b*, are designed to steady the frame-plates (which hold the arbor of the guides) against the dove-tail, *P P*, supported by brackets projecting from the front of the cheeks, sufficiently to let the block, *i*, which slides in the dove-tail, and holds the comb, be drawn forwards to give room for the hand to put in or take out the combs clear of the cutter. To the base of the dove-tail is screwed a plate, holding one of the centres for a worm-wheel, *k*, whose axis is made of steel, and has its end cut with a deep thread-screw; the screw-end of this axis works in a centre, fixed to the base of the dove-tail, and the block, *i*, is cut away to pass

clear over it and the threads of the screws, without touching them. The worm-wheel, *k*, is turned by an endless screw, on the arbor of the wheel, *r*, which receives its motion from the pulley, *t*, by an endless line. The block, *i*, which holds the comb, moves in the dove-tail, and is to carry the comb towards the cutters while cutting. As the screw on the axis of the wheel, *K*, is to carry the block up in lieu of a nut; a knife-edge, fastened to a small lever, *l*, moveable on a centre in the face of the block, is applied to it, and kept down (so that the knife-edge may take into the threads of the screw) by a catch similar to the latch of a door, which is released by pushing in a thumb-stud, and allows the spring, *o*, to throw up the lever, *l*, and disengage the screw, so that the block may be brought forwards in the dove-tail.

The piece of ivory intended to be cut into a comb, is put under a plate, *p*, and held down by two screws to the face of the block, which is in the same plane with the arbor of the cutters; the workman then puts down the knife-edge, and the catch keeps it so; he then turns the machine by his foot, and pushes the block towards the cutters (the comb resting close on the guides) till the knife-edge take the first thread of the screw, which turns round as before described, and pushes the block and comb up to the cutters, as far as the screw extends, and the cutters saw the teeth in the comb; the thumb-stud is then pushed in, and the spring, *o*, throws the knife-edge up, so that the block can be brought back by hand, and the comb taken out. The distance which the comb projects from the face of the block towards the cutters, and consequently the length of the teeth, is regulated by a straight edge of metal on the top of the block, *i*, under the plate, *p*, against which the back of the comb rests; it can be moved parallel to itself across the top of the block by two screws, (which are seen at the upper corners of the face of the blocks), for combs of longer or shorter teeth. The spindle of the crank has a wheel, *R*, on it, turning an arbor, *S*, by a line, which carries a set of cutters for pointing the combs. The arbor is shewn separately in *fig. 6*, and a cutter in *fig. 7*; it is made up in the same manner as the former one, and fastened by a screw, *T*; the ends of the teeth of the comb are applied to this cutter by hand, first on one side, and then on the other, till the points are made. This is performed to one comb, while the teeth are cutting in another.

Combustion

COMBUSTION, a fire, a burning, denotes the decomposition of certain substances, which are thereby called combustibles; accompanied with heat and light. The process of combustion, the various phenomena it exhibits, its astonishing effects, its infinite uses, and its devastations, have at all times, rendered it the principal object of human attention in all the various stages of life. The whole extent of civil economy, the preparation of food, as well as of almost all the articles of necessity and of luxury, most of the arts of more essential use to mankind, such as the manufactures of metals, of glass, of pharmacy, &c. depend almost entirely upon combustion. The inclemencies of the weather, and the dismal darkness of night, are removed by means of combustion. The most active instruments of destruction depend upon combustion. The greatest scenes of wonder, admiration, and terror, like the conflagration of towns, and the eruptions of volcanos, are those in which combustion is the sole actor.

Whilst the wants and the economy of the multitude, have at all times called forth their industry in devising easy methods of lighting and warming their apartments, of cooking their victuals, &c.; the calm contemplations of philosophers have endeavoured to investigate the cause or causes, the commencement, the progress, the various intensity, and the products of combustion. It is natural to suppose that their first ideas must have been extremely fanciful and incoherent; since the present theory, which rests upon the foundation of innumerable experiments and strict reasoning, is vastly different from

any sort of hypothesis, which even the wisest philosopher would have been led to form, without the light of those experiments.

The first plausible theory of combustion was formed by Stahl, an eminent chemist. The striking difference between bodies combustible and incombustible; that is, between bodies that are, and those that are not susceptible of combustion; induced him to suppose that the combustibles were endowed with a peculiar principle of inflammability, which the incombustibles had not, and to this supposed principle he gave the name of *phlogiston*. According to this supposition, when combustibles were heated to a certain degree, they began to part with this phlogiston, and continued to burn as long as they had phlogiston to lose; after which, they remained in a state of incombustibility; hence, in the former state, those bodies were said to be phlogisticated, and in the latter they were said to be dephlogisticated. With certain bodies the combustion was attended with a separation of other components, so that afterwards they could not be brought back to their former state by the mere addition of phlogiston; but with other bodies, as for instance, with the metals, the processes of dephlogistication and phlogistication might be repeated without end. Thus, a piece of zinc in the metallic state was supposed to be loaded with phlogiston, therefore, when exposed to a sufficient degree of heat, it would burn, *viz.* it would part with its phlogiston, and would thereby be reduced into the

state of a calx, destitute of phlogiston, and of the metallic appearance; but by placing this calx in contact with bodies which contained abundance of phlogiston, in a proper situation, the calx would thereby be enabled to recover its phlogiston, and with it its metallic state and combustibility. It might then be burnt again, and so forth. This plausible theory was no sooner made known, than it was eagerly adopted by philosophers and chemists; so that for a long period it remained the most prevailing theory of combustion. But though the theory was universally adopted, the existence of the principle upon which it was established could not be proved. There was no exhibiting the phlogiston by itself; and it was merely a supposition that a body acquired or lost its inflammability, according as it was combined with, or deprived of, its phlogiston. A supposition which, on a closer examination of facts, was found inadequate to the explanation of the concomitant phenomena. For instance, when a piece of zinc (and such was also the case with other combustibles as far as they might be subjected to experiments) of a determinate weight, was burnt and reduced to a calx, the weight of the calx was found to exceed the original weight of the zinc. It was, therefore, evident that it had acquired something ponderable, and this was utterly repugnant to the phlogistic theory, for by the loss of phlogiston it ought rather to have lost part of its original weight. In answer to this, a strange idea was suggested, namely, that the phlogiston was a principle of lightness; so that bodies became lighter by the addition of phlogiston and *vice versa*. But this supposition, so singular and so repugnant to the general laws of gravitation, was soon abandoned by philosophers when a variety of decisive experiments, the concurrence of recent discoveries in other branches of philosophy, and a strict mode of reasoning, introduced a new theory of combustion, which is both supported by accurate experiments, and sufficient to account for the phenomena. One of the principal labours in the experimental investigation, and the full establishment of this new and rational theory, was the unfortunate Lavoisier, to whose genius, and to whose persevering industry, the scientific world must ever think itself indebted.

In order to render this theory more easily understood by the reader, we shall prefix the following experiment. Take a glass vessel of a cylindrical shape, having a stopple capable of excluding the entrance or exit of any air, and let the outside of this vessel be graduated, so as to divide its capacity into pretty small portions. Put into this vessel, full of common air, a piece of dry phosphorus of a determinate weight; close the vessel tight, and heat gradually that part of it in which the piece of phosphorus stands, by means of the flame of a candle. As soon as the phosphorus has been heated to a certain degree, it takes fire of itself, burning with a flame and thick white smoke; but it soon ceases to burn. Suffer the vessel to cool, and the smoke will fall in the form of flakes, if the vessel and the air contained in it were quite dry, otherwise these flakes will melt in the moisture. If, in this experiment, the vessel be weighed before and after the combustion, it will be found precisely of the same weight. When the vessel is cooled to the actual temperature of the atmosphere, plunge the aperture of it under water, and in that situation remove the stopple. You will find that the water rises in it, which shews that a portion of the air has been destroyed or absorbed; in short, it has disappeared. By measuring the height of the water risen within the vessel, which is indicated by the graduation on the outside of it; in general, it will be found that about one quarter of the original quantity of air has

disappeared; and the remaining air will be found unfit for the combustion of phosphorus or of any other combustible; and is likewise unfit for the respiration of animals, so that if a bird, a mouse, or any other animal be confined in it, death will soon ensue. If the water which has rushed into the vessel be examined, it will be found to have contracted a sour taste indicating that an acid has been generated. If the vessel, instead of being opened in water be inverted and opened in quicksilver, then the flakes which in the preceding experiment were dissolved by the water, will now remain on the surface of the quicksilver. This is the acid of phosphorus, and if it be carefully gathered and weighed, it will be found together with the remaining phosphorus (if part of it remains unburned), equal to the weight of the original quantity of phosphorus together with the weight of the air that has disappeared. Therefore it is evident that the whole process of combustion consists in a decomposition of the purest part of respirable or atmospheric air; the pure part of it, which is about a quarter of the whole, is decomposed, its base is absorbed by the combustible, and generally communicates to it acid properties, in consequence of which that portion of the atmospheric fluid has been called oxygen gas, from the Greek; meaning the acidifying principle. Therefore, in combustion, the decomposition of the oxygen gas is effected by the burning body, when this body has been heated to a certain degree, which degree varies with the nature of the body. The base of the oxygen gas is absorbed and fixed by the burning body, which has thereby its weight increased, and its nature changed; whilst the caloric being disengaged, passes off in the state of sensible heat, and sometimes with such a portion of light as gives the appearance of red or white heat. Acids in general are formed from the absorption of oxygen during combustion. See OXYGEN GAS.

When the combustion is accompanied with red heat, but not with flame, it is called *ignition*. But ignition may also be applied to incombustible substances, for these may be rendered red or white hot, without suffering any decomposition. When a vapour arising from the heated body burns over it, it is then called *inflammation*; and when the inflammation is rapid and attended with noise, it is called *detonation*. Having now compendiously stated the new theory of combustion, it is necessary to add several necessary remarks respecting every part of it, which could not be intermixed with the theory without rendering it confused and less intelligible.

In the first place, since the process of combustion consists in a decomposition of oxygen gas, the generalizing spirit of modern philosophy includes every process, in which oxygen gas is decomposed, under the general name of combustion; thus, animal respiration, in which this gas is decomposed, its base absorbed, and heat evolved; may be reckoned amongst the processes of slow combustion. See RESPIRATION. The gradual absorption of oxygen by metallic bodies may also be reckoned amongst those processes.

Since combustion consists in a decomposition of oxygen gas, it naturally follows that without oxygen no combustion can take place. The oxygen, however, may be contained in other substances, in consequence of which those substances become capable of assisting combustion. Now there are seven of those substances, which, from their containing oxygen, are called *supporters* of combustion; and these are oxygen gas, atmospheric air, nitrous oxyd, nitric oxyd (which is procured by digesting copper and mercury in diluted nitrous acid, and collecting the gas which is extricated), nitric acid, oxygenized mu-

riatic acid, and hyperoxygenized muriatic acid. See the nature of those substances under the article GAS. It also follows that with a given combustible, the quickness of the decomposition is proportionate to the supply of oxygen, which shows the reason why a fire is increased by blowing common air, and much more by blowing oxygen gas upon it. But extris paucis with different combustibles, the fire is strongest when the combustible has the strongest attraction for oxygen. The flame of hydrogen gas urged by oxygen gas is reckoned to produce the most intense heat.

A combustible body, though exposed to oxygen, generally requires to be heated to a certain degree before the combustion commences. That degree varies with the nature of the body, and the purity of the oxygen; so much so that some of them, though not many, take fire immediately on being exposed to some of the above-mentioned supporters of combustion in the common temperature of the atmosphere, whilst others must be heated to a red and even to a white heat, before the decomposition takes place.

When the combustion has once commenced, the heat or caloric, in the form of sensible heat, which is extricated from the oxygen gas, raises the temperature of the adjacent parts of the combustible to that degree which is necessary for its combustion, and the heat evolved by the burning of this part heats the next and so on. But this is not the case with all sorts of combustibles; for some there are which must be kept up at a given high temperature in order to effect their combustion, and a diamond is of this sort. However the nature of combustibles in this respect varies according to the purity and quantity of oxygen. For instance, if a slender steel wire be exposed to the flame of a candle in common air, that part of it only will burn, which is acted upon immediately by the flame; but if the same wire be lighted by means of a bit of tinder, and then be plunged in a vessel full of oxygen gas, it will burn successively to the very end, like a slip of paper; exhibiting a remarkable bright light, and very considerable heat.

Of the simple bodies of nature, the chemists reckon three combustible ones, and two that are incombustible. The former are sulphur, phosphorus, and hydrogen; and the latter are azote and muriatic acid; but amongst the compound bodies, the combustibles are much more numerous. Such are oils, acids, and a vast variety of others which being of a fluctuating nature need not be particularly specified.

A variety of experiments, which may be found under the article GAS, prove that gasses owe their elastic nature to a considerable quantity of caloric, which must necessarily combine with their base, in order to assume the aerial form. Therefore, when, in consequence of the superior affinity of the combustible for oxygen, the oxygen gas is decomposed, and its base condensed, the caloric, which was necessary to its aerial form, being set at liberty, appears in the form of sensible heat; hence the heat which accompanies combustion is naturally supposed to proceed from the oxygen gas; and the quantity of it varies according to the rapidity of the process, so much so that in certain processes like the decomposition of oxygen effected by metallic substances in common air, it is not attended with any sensible degree of heat; for the heat evolved, being very slight, is instantly dissipated among the surrounding bodies.

With certain combustible bodies a peculiar process takes place. It is a remarkable slow process of spontaneous combustion. The body, by attracting oxygen from the atmosphere, becomes thereby gently heated, in consequence of which its affinity to oxygen is increased, a greater decomposition of the latter ensues, more heat is evolved, and thus the process is gradually accelerated until flame and

visible combustion take place. Such is sometimes the case with hay, the saw-dust of certain woods, and various other substances. The well known mixture of iron filings and sulphur moistened with a little water, is an instance of this sort; for if this mixture be buried a little below the surface of the ground, it will of itself, after the lapse of several hours, burst forth in a state of ignition. This experiment has been generally called the *artificial volcano*.

Though heat in combustion is derived from the oxygen gas, the derivation of light is not so evident. It has been for a long time supposed that this element also was one of the components of oxygen gas; but the observations made respecting the light yielded by several bodies when they are slightly heated, or even spontaneously, and that some of them yield much more light than others, seem to prove, that light forms a component principle of most bodies, and that it is evolved from the combustible. It is likely, however, that part of it may be derived from the oxygen also.

The following list of bodies subject to spontaneous inflammation is given by professor Bartholdi; meaning the inflammation occasioned by different bodies acting upon each other, without the aid of another body previously in a state of combustion.

1. Friction. Thus pieces of wood rubbed against each other are thereby inflamed. The best for this purpose are box-wood rubbed against mulberry, or laurel against poplar, or against ivy, &c. It is in consequence of friction that the wheels and axletrees of carriages sometimes take fire, when they are not sufficiently greased. In turning also, pieces of wood sometimes take fire.

2. The action of the sun's rays concentrated by lenses, or concave reflectors, or even by plane reflectors, provided their reflections be thrown upon the same spot. See BURNING-GLASS, and REFLECTORS.

3. The sudden slacking of quicklime has sometimes been known to produce the combustion of adjacent bodies.

4. The fermentation of animal and vegetable substances. Thus great accumulations of hay, turf, or flax, and hemp, heaps of linen rags in paper mills, &c. take fire, provided they are not quite dry; for without moisture, fermentation and the consequent evolution of heat cannot take place.

5. The accumulation of animal and vegetable substances covered with an oil, especially when the oil is of a drying quality. Thus lamp-black mixed with linseed oil is apt to take fire, and an earth of a brown colour, called the *black wad of Derbyshire*, sprinkled over with a little linseed oil, takes fire and appears red-hot like burning small coal, in about an hour's time.

6. There are several substances, which have the property of inflaming spontaneously, increased by torrefaction. Coffee, French beans, lentils, &c. are of this nature.

7. Sulphurated and phosphorated hydrogen gas. The cause of subterraneous fires and volcanoes in general, is attributed to the decomposition of pyrites, or metallic sulphurets, buried in the interior of the earth. These pyritous masses are decomposed by the contact and concurrence of water and air, and the decomposition is always accompanied with a great extrication of caloric, and a disengagement of a very inflammable gas, called *sulphurated hydrogen gas*. This gas inflames at an elevated temperature, and communicates the inflammation to the sulphur of the pyrites, to the coal and other bituminous matters, which generally accompany it.

8. Sulphuret and phosphuret of lime and of potash, formed in the combustion of several vegetables.

9. Phosphorus sometimes contained in charcoal.

COMBUSTION

The last particulars which we need take notice of, concerning the theory of combustion, are its products. But these must not be mistaken for those bodies which existed in certain combustibles, and have been left by themselves when the other components of the combustible have been separated, such as earthy particles, &c. The real products of combustion are those which did not exist before, and these, upon a strict examination, will be found to be either water, or an oxyde, or an acid. Water consists of oxygen

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and hydrogen. See WATER. An oxyde is a compound of the combustible with oxygen, but not such as to possess decided acid properties, (and the process is called *oxydation*), or an acid, which consists of the acidifiable part of the combustible, combined with oxygen sufficiently to give it decided acid properties. Thus, the combination of carbon and oxygen forms the carbonic acid gas, and this is produced in almost every combustion, also in respiration. &c.

Commerce

COMMERCE, the interchange of commodities, or the disposal of produce of any kind for other articles, or for some representative of value for which other articles can be procured, with the view of making a profit by the transaction. The term is usually restricted to the mercantile intercourse between different countries; the internal dealings between individuals of the same country, either for the supply of immediate consumption, or for carrying on manufactures, being more commonly denominated *trade*.

The mutual convenience of an exchange of commodities, must have been evident almost as soon as any part of mankind had acquired an idea of distinct property; the difficulty of communication between different countries must, however, have long rendered commercial intercourse very limited and uncertain. The dangers attending long journeys induced those who engaged in trading to distant parts, to associate together for mutual assistance and defence; and these companies of merchants, or caravans, were well adapted for the improvement of commerce, from the information which the individuals composing them would communicate to each other, and the connections they might occasionally form. In the book of Genesis, mention is made of the companies or caravans of Ishmaelite merchants trading in spices from Gilead into Egypt; to one of whom Joseph was sold, about 620 years after the flood. But this mode of communication between different countries was insufficient for the enterprising spirit of commercial adventurers; remote countries cannot convey their commodities by land to those places where, on account of their rarity, they are most desired, and consequently become most valuable. It was not till some progress had been made in the art of navigation, that the power was acquired of transporting with facility the superfluous stock of one part of the earth to supply the wants of another part, and that the active spirit of commerce could extend its multifarious concerns to all the known parts of the globe.

The Egyptians, soon after the establishment of their monarchy, are said to have opened a trade between the Arabian Gulph or Red Sea, and the western coast of the great Indian continent. The commodities which they imported from the east, were carried by land from the Arabian Gulph to the banks of the Nile, and conveyed down that river to the Mediterranean: but the maxims and manners of Egypt were inimical to commerce, and this profitable traffick soon declined.

The situation and circumstances of the Phenicians naturally led them to look to commerce as the only source from which they could derive opulence or power; and accordingly, the foreign trade carried on by them, particularly from Sidon and Tyre, became more extensive and important than that of any state in the ancient world. Their ships not only frequented all the ports in the Mediterranean, but they were the first who ventured beyond the ancient boundaries of navigation, and passing the straits of Gibraltar, visited the western coasts of Spain and Africa. They revived a commercial intercourse with Arabia and the continent of India,

on the one hand, and with the eastern coast of Africa on the other; the cargoes which they purchased in Arabia, Ethiopia, and India, being landed at Elath, the safest harbour in the Red Sea towards the north; thence they were carried by land to Rhinocolura, the distance not being very considerable, and, being re-shipped in that port, were transported to Tyre, and distributed over the world.

The wealth which the Phenicians acquired by monopolizing the commerce of the Red Sea, incited their neighbours, the Jews, under the prosperous reigns of David and Solomon, to aim at being admitted to some share of it. Solomon fitted out fleets, which, navigated by Phenician pilots and mariners, sailed from the Red Sea to Tarshish and Ophir, from whence they brought such valuable cargoes as suddenly diffused wealth and splendour through the kingdom of Israel. But the institutions of the Jews were by no means favourable to commerce, which was never carried to any great extent by them while they inhabited Judea.

The Carthaginians applied themselves to commerce and navigation with ardour, ingenuity, and success; but as the Phenicians had engrossed the commerce of India, their adventures were chiefly made to the west and north. Following the course which the Phenicians had opened, they extended their voyages beyond the shores of the Mediterranean, visiting not only all the coasts of Spain, but those of Gaul, and penetrating at last to Britain. They made voyages of discovery in different directions, and thus established a commercial intercourse with places which before were wholly unknown; but whatever knowledge of this kind they acquired, it was concealed from the inhabitants of other states with the utmost care.

The Greeks, although their country was almost encompassed by the sea, which formed many spacious bays and commodious harbours, and though it was surrounded by a number of fertile islands, were, notwithstanding such a favourable situation, a long time before they attained any degree of perfection in navigation. They scarcely carried on any commerce beyond the limits of the Mediterranean. Their chief intercourse was with the colonies of their countrymen planted in the lesser Asia, in Italy, and in Sicily. They sometimes visited the ports of Egypt, of the southern provinces of Gaul, and of Thrace, or passing through the Hellespont, they traded with the countries situated around the Euxine sea. The expedition of Alexander into the east considerably enlarged the geographical knowledge of the Greeks. He had observed the resources which commerce creates, in the exertions of the republic of Tyre, and therefore it became part of his plan to render the empire which he proposed to establish, the centre of commerce as well as the seat of dominion. With this view, he founded Alexandria near one of the mouths of the Nile, that, by the Mediterranean sea, and the neighbourhood of the Arabian gulph, it might command the trade both of the east and west. This situation was so judiciously chosen, that Alexandria soon became the chief commercial city in the world. Not only during the subsistence of the Grecian empire in Egypt and

in the east, but amidst all the succeeding revolutions of those countries, commerce, particularly that of the East Indies, continued to flow in the channel which the sagacity and foresight of Alexander had marked out for it, till the discovery of the navigation by the Cape of Good Hope opened a more expeditious and independent channel to all the maritime states of Europe.

In the early periods of the Roman history, commerce appears to have been much neglected and undervalued; it seems to have been thought a degrading employ by this military people, and to have been left almost entirely in the hands of the natives of the countries they conquered. The extent, however, of the Roman power, which included the greatest part of the known world, the vigilant inspection of the Roman magistrates, and the spirit of the Roman government, no less intelligent than active, gave such additional security to commerce, as animated it with new vigour; and, as soon as the Romans acquired a taste for the productions of other countries, commerce, particularly the trade with India through Egypt, was pushed with new vigour, and carried on to a greater extent. The pilots who sailed from Egypt to India first ventured to quit sight of the shore, and depending wholly on the trade winds, boldly sailed from Ocelis at the mouth of the Arabian gulph, across the ocean, to the coast of Malabar, returning with the eastern monsoon, and thus procuring the spices and other rich commodities of the continent and islands of the farther India, which were brought to the port of Mufiris by the Indians themselves. The commerce thus carried on will appear considerable even in the present age, as the trade with India is said to have drained the Roman empire every year of more than four hundred thousand pounds, and that one hundred and twenty ships sailed annually from the Arabian gulph to that country. The reign of Augustus was very favourable to commerce, as the peace which then prevailed over the civilized parts of the world, enabled the merchants to pursue it unmolested. Under Tiberius we find the Romans extending their protection to the north, and the town of Havern, the most ancient in Friesland, founded. Under Nero, the capital of England is first mentioned as a considerable place. Tacitus, who lived for some time at London, says it was famous for its many merchants, and plenty of its merchandize. Rome, however, as the seat of wealth and luxury, continued to be the metropolis of the commercial world, until the fourth century, when Constantine removed the seat of empire to Constantinople, and made it the emporium of commerce. This city was undoubtedly well adapted for that honour; it was favoured by nature with a fine climate, and in a most advantageous situation for carrying on an extensive correspondence with every part of the world then known.

The invasion by the northern nations in the fifth century, not merely arrested the progress of commerce, but effectually dissolved all commercial connections, and deprived the merchants of any market for their commodities. Europe became parcelled out into many small and independent states, differing from each other in language and customs; no intercourse subsisted between the members of these divided and hostile communities; their mode of life was simple, they had few wants to supply, and few superfluities to dispose of. Cities, in which alone an extensive commerce can be carried on, were few, inconsiderable, and destitute of those immunities which produce security or excite enterprise. It became disagreeable and dangerous to visit any foreign country, and thus the knowledge of remote regions was lost; their situation, their commodities, and almost their names, were unknown. The preservation of Constantinople from

the general destruction, however, prevented commercial intercourse with distant nations from ceasing altogether. In that city the knowledge of ancient arts and discoveries was preserved; a taste for splendour and elegance subsisted; the productions of foreign countries were in request; and commerce continued to flourish there when it was almost extinct in every other part of Europe. The merchants of Constantinople did not confine their trade to the islands of the Archipelago, or to the adjacent coasts of Asia; they took a wider range, and following the course which the ancients had marked out, imported the commodities of the East Indies from Alexandria. When Egypt was torn from the Roman empire by the Arabians, the industry of the Greeks discovered a new channel, by which the productions of India might be conveyed to Constantinople. They were carried up the Indus, as far as that great river is navigable; thence they were transported by land to the banks of the river Oxus, and proceeded down its stream to the Caspian sea. There they entered the Volga, and sailing up it, were carried by land to the Tanais, which conducted them into the Euxine sea, where vessels from Constantinople waited their arrival. This extraordinary and tedious mode of conveyance, Dr. Robertson observes, is a proof not only of the violent passion which the inhabitants of Constantinople had conceived for the luxuries of the east, and of the ardour and ingenuity with which they carried on commerce, but it demonstrates, that during the ignorance which reigned in the rest of Europe, a knowledge of remote countries was still preserved in the capital of the Greek empire. Robertson's Hist. Amer. vol. i.

The devastations of the Huns in Italy induced many of the richest inhabitants of the country near the bottom of the Adriatic, to fly with their best effects into the numerous small sandy isles lying amongst the shallow waters near the shores of the continent; on which isles, about seventy-two in number, they built such habitations as their circumstances would admit; and here by degrees arose the celebrated commercial city of Venice. Necessity first obliged them to devote themselves to commerce, the earliest branch of which was naturally the fisheries. Their next commercial object was the manufacture and exportation of salt. Thus by the application of its inhabitants, and the security of its situation, Venice gradually became the general magazine for the merchandize of the neighbouring continent, to which the many rivers that fall into the Adriatic sea greatly contributed; and as the Venetians in time became the carriers of this merchandize into distant countries, they were enabled to bring back raw materials for various manufactures which greatly enlarged their commercial dealings.

In this manner, Venice first, and Genoa, Florence, and Pisa afterward, from inconsiderable places became populous and wealthy cities, and laid the foundation for the revival of commerce throughout the Mediterranean, which, in process of time, was extended to the countries of Europe without the freights of Gibraltar. The free cities of Italy, were, for several centuries, the only places in Europe, west of the Eastern or Greek empire, which had any considerable commerce, or any valuable manufactures for the supply of other nations. Their merchants frequented Aleppo, Tripoli, Alexandria, and other ports of Syria and Egypt, where they procured the produce of India; and visiting the maritime towns of Spain, France, the Low Countries, and England, by distributing their commodities over Europe, communicated to its various nations some taste for the valuable productions of the east, as well as some ideas of manufactures and arts, which were then unknown beyond the precincts of Italy.

The first mention of the city of Antwerp, afterwards so famous for its trade, is in the year 517, when Theodoric expelled the Danes from it. Some towns in England, as Chichester and Abingdon, are said to have been founded about this time, which shews that trade and manufactures were gaining ground in this country.

The unsettled state of Europe, arising from the fierce and restless disposition of the barbarous tribes who had taken possession of the western empire, caused for several centuries a great stagnation of commercial intercourse. Venice however continued to improve its commerce, and London became "a mart town of many nations, which repaired thither by sea and land." Some of the Italian cities began to assume a degree of independence, and several towns were founded in Germany and Flanders, which afterwards became of much commercial importance. The commerce of Europe revived a little under the government of Charlemagne, who, among other endeavours to promote it, is said to have formed a project for uniting the two great rivers of the Rhine and the Danube, and thus forming a communication between the German ocean and the Black sea, without sailing up the Mediterranean. But his engineers had not sufficient skill to overcome the difficulties they met with, and the undertaking was soon relinquished. In a letter from this prince to Offa, king of Mercia, he grants leave for such English as went in pilgrimage to Rome, to pass through his dominions free; but such as travelled for the purposes of trade were to pay the customary tolls; and promises that the merchants should have legal patronage and redress of grievances. These merchants were probably persons who carried their whole stock with them, which of course could not be of any very great amount.

The establishment of Christianity in Germany produced a much more intimate and regular correspondence between the north of Europe, and the earlier Christianized countries of Italy, France, Spain, and Britain; so that their superfluities and produce were mutually communicated to each other, while Germany received by degrees, from its intercourse with those countries, considerable improvements with respect to agriculture, mining, vine-dressing, manufactures, and the arts, more immediately conducive to the comforts of civilized life. It considerably increased the cities and towns, where cathedral churches and houses for the bishops and clergy were erected. Thus the propagation of Christianity greatly favoured the advancement of commerce in the north of Europe; while Charlemagne by his conquest of Italy, and by rebuilding and restoring many of the decayed cities of that country, inspired those cities with the spirit of commerce, manufacture, and navigation, for which they became in after times so justly famous. This period may be considered as the first dawn of the revival of commerce in Europe; for although subsequent to this time the Saracens or Moors, and the Normans, by their ravages and conquests in various parts, greatly obstructed and retarded its progress, yet in spite of all opposition, the free cities in both the extreme parts of Europe in consequence of the increase of their wealth and population from the encouragement of commerce, gradually arose to very considerable importance.

In the tenth century, the commercial intercourse which the Germans had previously cultivated with the neighbouring states was much increased by the discovery of valuable silver mines at Goslar in Saxony, which occasioned other parts of Germany to be explored for mines with considerable success. The woollen manufacture of Flanders began to acquire some degree of importance, being much encouraged by Baldwin, third earl of Flanders, who invited into

the country all manner of handicraftsmen for making all sorts of manufactures, to whom he granted great privileges. He also established annual fairs, and fixed markets on stated days of the week at Bruges, Courtray, Torhout, Mont-Cassel, and other places, where merchants could exchange their goods for others; for "by reason of the scarcity of money at that time, the Flemings dealt mostly by permutation, or barter of one kind of merchandize for another; which we read was also the practice of almost all the Germans and Sarmatians."

The republic of Venice had now acquired so much wealth and strength by the great extension of her commerce, as to have become a formidable political state, and having annexed to their dominions many cities and towns on the east coast of the Adriatic sea, the doge of Venice assumed the title of duke of Dalmatia. They established a regular commercial intercourse with the Saracens of Egypt and Syria, "countries ever famous for the production of rice, sugar, dates, senna, cassia, flax, linen, balm, perfumes, galls, wrought silk, soap, &c. besides the rich spices and precious stones of India, brought to those two countries; with all this rich merchandize, the Venetians now traded all over the western parts of Europe, to their immense profit." They obtained from the Greek emperors a freedom from all customs and taxes in their empire; and in the year 996 the emperor Otho III. likewise granted them various privileges, with a right to set up fairs in several parts of Germany, where they carried on a vast commerce.

The crusades contributed materially to the extension of commerce during the 11th and 12th centuries. The Genoese, the Pisans, and the Venetians, furnished the transports necessary to carry the vast armies that embarked on these wild enterprizes: they also supplied them with provisions and military stores. Besides the immense sums which they received on this account, they obtained commercial privileges and establishments of great consequence, in the settlements which the crusaders made in Palestine, and in other provinces of Asia. From these sources they acquired great wealth, and a proportionate increase of power. By the expeditions into Asia, the inhabitants of all the states of Europe had an opportunity of observing the manners, the arts, and the accommodations of people more polished than themselves. The adventurers who returned from Asia communicated to their countrymen the ideas which they had acquired, and the habits of life they had contracted by visiting more refined nations. The Europeans began to be sensible of wants with which they were formerly unacquainted; and such a taste for the commodities and arts of other countries gradually spread among them, that they not only encouraged the resort of foreigners to their harbours, but began to perceive the advantage and necessity of applying to commerce themselves.

The great commercial progress of the city of Lubeck soon caused other towns to be founded in the neighbourhood of the Baltic; which, suffering much from the occasional attacks of neighbouring powers, and the depredations of pirates, were induced to enter into an association for their mutual safety, and the protection of their navigation. Thus was gradually formed the famous Hanseatic confederacy, which made so great a figure in the commercial history of several succeeding centuries, and of which Lubeck was from the first considered as the director or head. Werdenhagen fixes on the year 1169 for the first of this confederacy, which consisted of the twelve following towns on the Baltic shore: viz. Lubeck, Wismar, Rostock, Stralsund, Grypswald, Anclam, Stetin, Colberg, Stolpe, Dantzick, Elbing,

and Koningsberg; though probably not all of them at the first; as some of them do not appear to have been founded till a later period. Lambecius, librarian to the emperor Leopold, is of opinion, that the Hans-league did not properly commence till after the league between Lubeck and Hamburgh in 1241, at which time the towns comprehended in this association were in possession of all the commerce of the south shores of the Baltic, from Denmark to the bottom of the gulph of Finland, besides an extensive commerce to more distant parts. About this time the commerce of Norway began to acquire some degree of importance, and in a treaty between the monarch of that country and Henry III. of England, in 1217, it was agreed that their respective states should be free for merchants and others on both sides.

At the beginning of the 13th century, the German merchants of the Steel-yard engrossed all the foreign commerce which then existed in England, which at that time had very few merchants, and fewer ships of her own. About 1250, however, a society of English merchants was formed, who are said to have had privileges granted to them in the Netherlands, by John duke of Brabant; whither they had begun to resort with English wool, lead, and tin, bringing in return fine woollen cloths, linen, and other articles. From this society, the company styled "Merchants of the staple of England" took its rise. In 1274, a treaty was concluded with the earl of Flanders for the settlement of some commercial disputes which existed between the two countries.

France at this period possessed very little foreign commerce, but in the cities of Italy it had increased greatly. The republic of Genoa was in its meridian glory, being the greatest maritime power then existing. Even Venice, great as it was now become, was eclipsed by Genoa, which, towards the conclusion of this century, had reduced the republic of Pisa, till then also powerful at sea, to the lowest ebb of fortune, never again to rise to greatness, and soon to lose her independence.

A new æra was now about to commence in commercial history. The discovery of that valuable, but now familiar instrument, the mariner's compass, Dr. Robertson observes, may be said to have opened to man the dominion of the sea, and to have put him in full possession of the earth, by enabling him to visit every part of it. But the effects of this discovery were not so sudden or extensive as might be expected. The use of the compass enabled the Italians to perform the short voyages to which they were accustomed, with greater security and expedition, but near half a century elapsed, before navigators ventured into any seas which they had not been accustomed to frequent. One of the first fruits of such adventures, was the discovery of the Canary islands by the Spaniards.

Many of the princes of Europe were now becoming more sensible of the importance of commerce, which led them to enter into treaties for its regulation and defence. Edward I. in 1302 published his famous charter styled *Charta Mercatoria*, by which "The merchants of Almaine, France, Spain, Portugal, Navarre, Lombardy, Florence, Provence, Catalonia, Aquitaine, Thoulouse, Flanders, Brabant, and of all other foreign parts, who shall come to traffic in England, shall and may safely come with their merchandize into his cities, towns, and ports, and sell the same, by wholesale only, as well to natives as to foreigners." Some particular articles they were allowed to sell by retail; and they were to export any goods they might want from England on paying the usual customs, except wine, which could not be exported without a special licence. The countries here mentioned shew the

parts to which the commerce of England was at that time chiefly confined; and a very good idea of its extent may be gained from the following account of the exports and imports, in the 28th year of Edward III. from a record in the Exchequer.

<i>Exports.</i>	£.	s.	d.
31,651½ sacks of wool, at six pounds per sack, and 3036 hundred weight and 65 fells, each hundred weight being 6 score, at forty shillings per hundred weight, with the customs, &c. thereon, amounted to	277,606	2	9
Leather, with its custom	96	2	6
4774½ coarse cloths, at 40 shillings each, and 8061½ pieces of worsted, at 16s. 8d. per piece	16,266	18	4
Customs thereon	215	13	7
Total Exports, with the duties thereon	294,184	17	2

<i>Imports.</i>	£.	s.	d.
1831 fine cloths, at 6l. per cloth, which, with the customs, comes to	11,083	12	0
397½ hundred weight of wax, at 40 shillings per hundred weight, which, with the customs, comes to	815	7	5
1829½ tons of wine, at 40 shillings per ton, which, with the customs, comes to	3,841	19	0
Linen cloth, mercery, grocery, and all other wares whatever	22,943	6	10
On which the custom was	285	18	3
Total Imports, with the duties thereon	38,970	3	6

Thus, as sir William Temple observes, "when England had but a very small foreign commerce, we were rich in proportion to our neighbours, by selling so much more than we bought." It is not very probable, however, that the excess of the exports was generally so great as is here stated.

The materials of commerce were now increasing by the improvement of manufactures in various parts of Europe; while the discoveries of the Portuguese on the coast of Africa, and in the adjacent seas, excited a more enterprising spirit of mercantile adventure, and at length, in 1487, led to the discovery of the Cape of Good Hope, which they doubled about ten years after, and thus accomplished the first regular voyage to the East Indies. About the same time also was accomplished the great discovery of the western continent. These events, which filled the world with astonishment, and gave rise to an infinity of new speculations, have since supplied it with a prodigious increase of wealth, and with many new and excellent materials for the immense additional commerce which has thus accrued to all the states of Europe.

The whole of the vast regions discovered in the East and West, was by the papal authority divided between the Spaniards and Portuguese. The former first made herself mistress of the islands, and next of the principal part of the continent of America; in consequence of which the cities of Seville and Cadiz became the store-houses for the riches of the newly-discovered western world. Portugal pursued her commerce and rapid conquests in the East Indies, so that

Lisbon soon became (what the now declining city of Venice had been for many centuries past) the great magazine for all the rich productions of the East. They had also discovered Brazil in South America, which soon became an almost inexhaustible fund of wealth to Portugal, which may be said to have been then at the height of its commercial greatness.

In the course of the 16th century many circumstances occurred which contributed greatly to the extension of commerce. The English in the pursuit of a north-west passage to India had discovered the whole coast of North America, where, after some years, they began to attempt settlements. They engaged in the Newfoundland fishery, and also in the whale fishery at Spitsbergen or Greenland. The continual jealousies and disputes between the English merchants and the German Hanseatic merchants of the Steel-yard in London, were at length terminated by the abolition of the peculiar privileges of the latter. The discovery of a passage to Russia round the north Cape of Lapland, opened a field for other new discoveries, and new branches of commerce; in consequence of which a company for trading to Russia was immediately formed and incorporated. The commerce with Turkey was encouraged by the incorporation of a company; and the intercourse with Guinea and other places on the coast of Africa, was also thought of sufficient importance to have a company established for carrying it on.

While the importance of the Italian cities was declining, and the commerce of the towns on the Baltic experiencing some diminution, the cities of Hamburgh and Antwerp had risen into considerable importance. The latter in particular, from the convenience of its situation, might for some time be considered as the centre of the commerce of Europe, as well for the merchandize of both the Indies, as for the naval stores and other bulky commodities of the northern states. It was however soon to find a rival among its industrious neighbours in the United Provinces, who, from the time of their independence, applied themselves to manufactures and commerce with the utmost assiduity. France was at this time beginning to encourage the cultivation of the vine, and the improvement of her broad silk manufacture; while Spain, by expelling the protestants from the Netherlands, supplied England, Holland, and the Hanse towns with great numbers of wealthy and industrious manufacturers and artificers, as well as with an accession of many ingenious and beneficial new manufactures.

The 17th century was the period in which the principles were adopted, and most of the establishments formed, which have contributed to advance the commerce of Europe to its present astonishing height. The interests of nations became better understood than in any former age; the utility of commerce had become evident to every one, from the wealth and power it had conferred on the states which had encouraged it; and commercial treaties became frequent between the different nations. Navigation was improved; new settlements were formed, and many of those before made were rising into importance; manufactures were advancing in many parts of Europe; shipping was increasing, and the intercourse between distant places, from the accumulation of knowledge and experience, becoming more expeditious and secure.

The lucrative commerce of the East became one of the leading objects of mercantile pursuit. An English East India company was formed in 1600; and the Dutch companies, which were united in 1602, became one of the most celebrated commercial establishments ever formed. The French visited the East Indies in 1601, but did not establish a regular company for carrying on the trade till 1664. The

Danes established an East India company in 1617, and in 1627 the king of Sweden issued letters patent for forming an East India company, but it was not carried into execution till some years after. The Spaniards and Portuguese, however, at this period, possessed by far the greatest share of the commerce of India, which had now become very considerable. The following account published by Mr. Munn, in 1621, of the quantity of Indian merchandize consumed annually in Europe, gives a very good idea of the proportion of the different articles of this branch of commerce: the prices affixed are the prime cost in India, including all charges till actually shipped for Europe.

	s.	d.
6,000,000 lb. pepper, at	0	2½ per lb.
450,000 lb. cloves, at	0	9 per lb.
150,000 lb. mace, at	0	8 per lb.
400,000 lb. nutmegs, at	0	4 per lb.
350,000 lb. indigo, at	1	2 per lb.
1,000,000 lb. raw silk, at	8	0 per lb.

This statement was probably meant to include only the principal articles; at least it is certain that about 1631 several other kinds of merchandize were usually imported from India, as taffaties, painted calicoes, drugs of various sorts, and China ware. Tea, the great object of commercial intercourse with China, was either not yet an object of commerce, or was imported in such small quantities, that in England at least, in 1660, it was not thought of sufficient consequence to be subjected to a duty.

Dr. Davenant, who published his "Discourses on Trade" in 1698, was of opinion, that from about the year 1656 to 1688, England had every year gradually increased in riches; and that about the last mentioned year, the increase or addition to the wealth, and general stock of the nation, arising from foreign trade and home manufactures, was at least two millions per annum. In this estimate the different branches of trade are stated as follows:

The plantation trade may bring in	-	£ 600,000
The East India trade may bring in	-	500,000
The European, African, and Levant trade, by our own product may bring in	-	600,000
Ditto, by re-exports of plantation goods	-	120,000
Ditto, by re-exports of East India goods	-	180,000
Total		2,000,000

This account is probably somewhat beyond the truth, with respect to the period to which it refers; but that there had been a considerable influx of wealth, is shewn by the observations of the same author, that from the year 1600 to 1688, the general rental of England was nearly trebled, and the purchase of land half doubled; that the stock of the kingdom was multiplied above five fold, and the money in circulation above four fold. This rapid advance in wealth, can be ascribed to no other cause than the improvement of commerce, which was now becoming of the utmost importance to all the European states, particularly to such as were desirous of maintaining any degree of naval power.

The increase of wealth arising from the extension of commerce, gave rise to the establishment of banks, by which its operations have of late years been so much facilitated. The commercial cities of Venice and Genoa had long experienced the utility of such institutions, which were now adopted in other states. The banks of Amsterdam, of

Hamburgh, and of Rotterdam were established; and in 1694, the bank of England, and the bank of Scotland. The business of private bankers likewise took its rise, and had become considerable, when it received a severe check from the unjustifiable conduct of Charles II. in seizing the money which the bankers had advanced on credit of the taxes. This branch of mercantile intercourse has however been since carried to an extent which in former times would have been deemed wholly incredible.

Thus, with its principles generally understood; with most of the establishments formed which are necessary to facilitate its operations; with laws and treaties in force for its encouragement and protection; markets established for the purchase or sale of commodities in almost every part of the globe; navigation brought to a high degree of perfection, vast improvements in arts and manufactures; and a great increase of artificial wants from the progress of luxury and refinement; the commerce of the world, and particularly of Europe, has, during the 18th century, expanded in an astonishing degree, and become intimately connected with the political existence of almost every state.

COMMERCE of Great Britain. The most authentic materials from which an idea can be formed of the progress and extent of the commerce of Great Britain, are the accounts kept in the office of the inspector-general of exports and imports, at the custom-house of London. These accounts do not shew the current value of the commodities exported or imported, but are formed from their quantities, according to certain rates of value affixed to the several articles of foreign trade in 1696, by which they have been rated ever since. It is evident, therefore, that, as the price of all kinds of merchandize is subject to great fluctuation, and in general has much increased in this country within the last hundred years, these accounts are far from shewing the actual values in the later years; they are, however, from this very circumstance of being uniformly made up at the same rates, the better adapted to a comparative view, and shew a progressive increase which has arrived to an amount never before known in the commerce of any nation. According to these estimates the total amount of the exports and imports of Great Britain have been as follows:

Years.	Imports.	Exports.
1700	£ 5,970,175	£ 7,302,716
1701	5,869,606	7,621,053
1702	4,159,304	5,235,874
1703	4,526,596	6,644,103
1704	5,383,200	6,552,019
1705	4,031,649	5,501,677
1706	4,113,933	6,512,086
1707	4,274,055	6,767,178
1708	4,698,663	6,969,089
1709	4,510,593	6,627,045
1710	4,011,341	6,690,823
1711	4,685,785	6,447,170
1712	4,454,682	7,468,857

At the conclusion of the war, by the peace of Utrecht, a commercial treaty with France was likewise negotiated: but when the particulars of it came to be discussed, two of the articles, by which the produce and manufactures of France were to be admitted into this country on the same terms as those of the most favoured nation, excited such general disapprobation, that the bill for carrying it into effect was rejected by the house of commons. The strongest objection to the principle of the treaty, was that it might ruin the trade then carried on with Portugal, which was

considered as the most valuable branch of our European commerce.

It is evident, that from the year 1705, notwithstanding the disadvantages it always labours under in time of war, commerce had been gradually increasing; but when peace enabled it to return to its usual channels, and restored some branches which had been considerably interrupted, its general advancement became more obvious, and although from the mode then usually adopted, of judging of the profits of commerce merely by the excess of the value of the exports, the balance appeared less than it had been in former years, the wealth which flowed into the country from foreign trade, being no longer absorbed in public loans, soon enabled the government to make a permanent reduction in the legal rate of interest. The war with Spain in 1718, did not cause much interruption of commercial intercourse, except in the direct trade with that country.

Years.	Imports.	Exports.
1713	£ 5,811,077	£ 7,352,655
1714	5,929,227	8,361,638
1715	5,640,943	7,379,409
1716	5,800,258	7,614,085
1717	6,346,768	9,147,700
1718	6,669,390	8,755,302
1719	5,367,499	7,709,528
1720	6,090,083	7,936,728
1721	5,768,510	8,681,200

At this period the judicious principle of promoting the exportation of British manufactures, which had hitherto been applied only to woollen goods, was extended to British manufactures and produce in general; which were allowed to be exported duty free, except a few articles chiefly materials for manufactures, the exportation of which it would not have been proper to encourage; while drugs and other materials used for dyeing, were, upon being first duly entered, to be imported duty free, but upon re-exportation were to pay specific duties. For this highly beneficial regulation, so simple in its principle, and so comprehensive in its extent, the country was indebted to the enlightened wisdom of Mr. Walpole: the experiment excited much doubt and solicitude as to its success, but it soon appeared that the loss of revenue in the duties thus given up, was a mere trifle in comparison with the stimulus it gave to manufactures and the consequent extension of commerce.

Years.	Imports.	Exports.
1722	£ 6,378,098	£ 9,650,789
1723	6,505,676	9,489,811
1724	7,394,405	9,143,356
1725	7,094,708	11,352,480
1726	6,677,865	9,406,731
1727	6,798,908	9,553,043
1728	7,569,299	11,631,383
1729	7,540,620	11,475,771
1730	7,780,019	11,974,135
1731	6,991,500	11,167,380
1732	7,087,914	11,786,658
1733	8,016,814	11,777,306
1734	7,095,861	11,000,645
1735	8,160,184	13,544,144
1736	7,307,966	11,616,356
1737	7,073,638	11,842,320
1738	7,438,960	12,289,495

The above period was almost wholly a time of peace, during which the commerce of Great Britain was gradually

advancing, both from the improvement of several of the existing branches, and the acquisition of new ones. The South-sea company undertook the Greenland whale fishery, which had been entirely relinquished by this country for some years past; and encouragement was given to fisheries on the coast of America. Attempts were made to obtain a share of the fur trade of north America, which was almost entirely in the hands of the French. The Ostend East India company, which had been found prejudicial to the English trade in those parts, was suspended; while our trade with China increased considerably, particularly in the article of tea. The trade of the Levant company was very flourishing; as was likewise that of the Hudson's bay company, though the latter was but of small extent. The produce of several valuable commodities was at the same time augmenting, from an increased cultivation of rice in the American colonies, and of coffee in the West India islands, while great quantities of corn were annually exported from Great Britain to France, Portugal, Spain, and Italy.

The war which began in 1739, was occasioned chiefly by disputes respecting our commerce in the West Indies, which had been much interrupted by the Spaniards. It caused, at first, some decline of foreign trade, which however soon regained the extent to which it had been carried during the preceding peace.

Years.	Imports.	Exports.
1739	£ 7,829,373	£ 9,495,366
1740	6,703,778	8,869,939
1741	7,936,084	11,469,872
1742	6,866,864	11,584,427
1743	7,802,353	14,623,653
1744	6,362,971	11,429,628
1745	7,847,123	10,497,329
1746	6,205,687	11,360,792
1747	7,116,757	11,442,049
1748	8,136,408	12,351,433

At this time, a much greater proportion of the exports consisted of unmanufactured produce than it has since; as it appears there had been exported from England in five years, from 1744 to 1748, no less than 3,768,444 quarters of corn, which at medium prices was worth 8,007,948 l.

That a considerable increase of commerce had taken place, is evident from the quantity of shipping employed. The total tonnage of vessels that cleared outwards on an average of three years preceding the war, had been 503,568 tons; the average of the three years, ending with 1751, was 661,184 tons. The encouragement of the fisheries, and the regulation of the Guinea or African trade, which had been in the hands of an exclusive company, but was now in a great measure laid open; caused some extension of foreign trade, although the Levant, or Turkey trade, which had been considered as one of the most valuable branches, was beginning to decline rapidly, from the French improving the natural advantages they possess for a trade with those parts.

Years.	Imports.	Exports.
1749	£ 7,917,804	£ 14,099,366
1750	7,772,039	15,132,004
1751	7,943,436	13,967,811
1752	7,889,369	13,221,116
1753	8,625,029	14,264,614
1754	8,093,472	13,396,853
1755	8,772,865	12,182,255
1756	7,961,603	12,517,640
1757	9,253,327	13,438,285
1758	8,415,025	15,034,994

Years.	Imports.	Exports.
1759	8,922,976	14,696,892
1760	9,832,802	15,579,079
1761	9,543,901	16,365,953
1762	8,870,234	14,134,093

It is evident that commerce had not been very materially affected by the war. The years 1755 and 1756 marked the lowest point of its depression; whence it gradually rose, till it had gained a superiority over the unexampled traffic of 1750, a year of established peace and security.

By the peace of 1763, although many islands which had been taken in the West Indies were restored, Great Britain retained a number of newly acquired islands, perhaps more than could be immediately brought into cultivation with advantage. The arrangements respecting Asia were very favourable to the East India company, and in Africa an exclusive trade was secured in the article of gum Senegal, a material indispensably necessary to the perfection of many of our manufactures. The immediate consequence, however, of the acquisition of additional territories, was, that a wide field was opened for speculation and commercial enterprise, which caused much productive capital to be withdrawn from the trade and manufactures of Great Britain; yet our merchants were not only able to maintain their own credit, but also to assist their correspondents during the commercial embarrassments in Holland and other parts of the continent.

In 1765, the principles and measures were adopted which soon involved the country in disputes with its American colonies. Impolitic restrictions were laid on a beneficial intercourse which had long subsisted between the British colonies and the Spanish West India settlements; which being soon followed by other causes of discontent, drove the Americans into public resolutions to make no further importations from Great Britain, but such as were unavoidably necessary, and to encourage, to the utmost of their power, every kind of manufacture that was practicable among themselves. This step soon produced serious effects in Great Britain; the merchants connected with America found themselves unable to fulfil their engagements by the stoppage of large sums due to them from that country; the whole system of their business was deranged, and general distress spread through the circle of their connections; the manufacturers suffered by the want of regular payments from the merchants, while their materials, and made up goods, to an alarming amount, were becoming a dead stock upon their hands; in consequence of which, great numbers of workmen were thrown out of employ. Petitions were presented to parliament from all the trading and manufacturing towns, which probably had some effect in procuring a temporary adjustment of the dispute.

The non importation agreement in America, was renewed in 1769 and 1770; yet the commerce of Great Britain, notwithstanding these interruptions of an important branch of it, continued to increase; and previous to the war which followed, had attained to a greater extent than in any former years.

Years.	Imports.	Exports.
1763	£ 11,665,036	£ 16,160,181
1764	10,364,307	16,512,403
1765	10,889,742	14,550,507
1766	11,475,775	14,024,964
1767	12,073,956	13,844,511
1768	11,878,661	15,117,982
1769	11,908,560	13,438,236

Years.	Imports.	Exports.
1770	12,216,937	14,266,653
1771	12,821,995	17,161,146
1772	14,508,715	18,732,379
1773	12,522,643	16,654,052
1774	14,548,902	17,607,447

The prohibition of all trade and intercourse with the American colonies excited serious alarms, not only on account of the loss of a valuable branch of trade; but from the supposed encouragement which the acquisition of it would give to the trade of those powers who assisted the colonies. These apprehensions, however, in a few years appeared to be in a great measure groundless, many British manufactures found their way to America, though not imported directly from hence; and Mr. Chalmers observes, that "there was an evident tendency in our traffic to rise in 1779, till the Spanish war imposed an additional burthen. There was a similar tendency in 1780, till the Dutch war added, in 1781, no inconsiderable weight. And the year 1781, accordingly, marks the lowest degree of depression, both of our navigation and our commerce, during the war of our colonies. But with the same vigorous spirit, they both equally rose, in 1782, as they had risen in former wars, to a superiority over our navigation and commerce, during the year wherein hostilities with France began."

Years.	Imports.	Exports.
1775	£ 14,816,955	£ 16,946,523
1776	12,449,189	15,685,107
1777	12,643,834	14,152,243
1778	10,975,533	12,375,712
1779	11,435,263	13,597,771
1780	11,714,967	13,689,073
1781	12,723,613	11,470,388
1782	10,341,623	13,224,637

The opportunity of renewing the commercial connections between this country and America, from the conclusion of peace, was eagerly embraced; but subsequent experience proved, that a greater degree of caution had now become necessary to render it a beneficial trade. The arrangements relative to the commerce of Ireland, had a very beneficial effect in that country, which had hitherto been excluded from almost every species of commerce, and refrained from sending the produce of her own soil to foreign markets. The convention with Spain settled more accurately the limits within which British subjects were allowed to cut logwood on the Musquito coast, and consequently gave greater certainty and security to the trade with those parts. The commercial treaty with France, by discontinuing many of the prohibitions and prohibitory duties which had existed for almost a century between the two nations, opened a wide field for speculation and adventure. The consolidation of the customs by the abolition of all the confused and complex duties which then existed, and the substitution of a single duty on each article in their stead, was a measure of great convenience to all persons engaged in mercantile transactions. Under all these circumstances, supported by the improvements which had taken place in several of the principal manufactures, the foreign trade of Great Britain increased greatly during the peace, and in the year 1792, had attained to an unparalleled height, both in point of value, and with respect to quantity of shipping employed in it.

Years.	Imports.	Exports.
1783	£ 13,122,235	£ 15,450,778
1784	15,272,802	14,961,074
1785	16,279,490	16,770,239
1786	15,786,072	16,300,730
1787	17,804,024	16,870,114
1788	18,027,170	17,472,408
1789	17,821,102	19,340,548
1790	19,130,886	20,120,121
1791	19,669,782	22,731,995
1792	19,659,358	24,905,200

The total number of vessels which belonged to the several ports of the British empire on the 30th September 1792, was 16,079; the amount of their tonnage 1,540,145 tons; and the number of men and boys usually employed in navigating them 118,286. The number of vessels that entered inwards at the several ports of Great Britain (including their repeated voyages) was as follows:

	Ships.	Tons.
British - - -	12,030	1,587,645
Foreign - - -	2,477	304,074
Total	14,507	1,891,719

At this period, the commerce of Great Britain was generally admitted to be in a very flourishing state. The application and improvement of machinery in almost every branch of manufacture, had reduced the charges of workmanship so far, as to enable our manufacturers to supply foreign markets on better terms than any other country could offer; while the increase of capital, arising from the accumulation of the profits of successful commerce during a period of peace, gave our merchants the means of allowing longer credit than could be obtained elsewhere. The high price of the public funds, led many persons to employ their money in discounting private securities, which greatly facilitated the extension of commercial credit, but probably tempted some to trade much beyond the amount which their capital justified, or to speculate largely without any real property of their own; so that when the apprehension of war produced a greater degree of caution, and began to affect particular branches of trade, many were involved in embarrassments; and on the commencement of the war in 1793, commercial concerns, in general, experienced a serious shock. The assistance afforded by government to such houses as appeared to be really solvent, by lending them exchequer bills for a certain time, operated very successfully, and averted the consequences that were apprehended; credit revived, and as the war in its progress almost annihilated the foreign trade of some of the powers engaged in it, the commerce of Great Britain received a considerable augmentation; and, protected by its naval superiority, continued to increase, notwithstanding all the measures which political animosity could devise to obstruct or destroy it.

Years.	Imports.	Exports.
1793	£ 19,256,717	£ 20,390,180
1794	22,288,894	26,748,967
1795	22,736,889	27,312,338
1796	23,187,319	30,424,184
1797	21,013,956	28,917,010
1798	27,857,889	33,591,777
1799	26,837,432	35,991,329

Years.	Imports.	Exports.
1800	30,570,605	43,152,019
1801	32,795,557	42,301,701

In 1803	£ 40,100,870
1804	40,349,642
1805	41,068,942
1806	43,242,176

The increase during the above period, though really very great, was not however equal to what it would appear from the above accounts to have been. This irregularity in the comparative view which the account of imports and exports generally furnishes with sufficient accuracy, of the commerce of Great Britain, arises from the article of coffee, the import of which was formerly little more than sufficient to supply its small consumption in this country. But the interruption of the trade of France, the conquest of their West India islands, and the greatly increased cultivation of coffee in Jamaica, caused nearly the whole supply of the continent with this commodity to depend during the war on Great Britain. In the inspector-general's book of rates, coffee is valued on importation at 7*l.*, and on exportation, at no less than 14*l.* 10*s.* per cwt.; while, during the above period, the real average value was about 5*l.* per cwt. when imported, and 5*l.* 10*s.* when exported. The official account, therefore, from 1794, when coffee suddenly became a very considerable article of exportation, requires some correction; and if the over-estimated value of this article is deducted, the exports of the year 1800 will appear to have been 38,120,120*l.*, and of 1801, 37,786,856*l.*

The short interval of peace in 1802, produced an immediate extension of foreign trade; and Mr. Addington thought himself justified "in pronouncing the commerce of the country to be in a state of unrivalled and unexampled prosperity." The value of British manufactures exported, considerably exceeded the preceding year, and the total amount of the exports, according to the official values, was 46,120,962*l.* But in this and the succeeding years, it will be proper to adopt the correction just mentioned, which will give the amount of the imports and exports as follows:

Years.	Imports.	Exports.
1802	£ 31,442,318	£ 41,411,966
1803	27,992,464	31,578,495
1804	29,201,490	34,451,367
1805	30,344,628	34,954,845
1806	31,094,089	36,528,132

The account of imports for the last year is not quite correct; the imports from the East Indies for that year being incomplete.

Almost every article being greatly under-valued in these accounts (except in one or two instances) the total must give a very inadequate idea of the real extent of the commerce of Great Britain. Some idea may be formed of the under-valuation of the imports by those of the East India company, taking the account of their sales as the importation; the medium value of which, on an average of three years, was 6,100,000*l.*; whereas, the medium value by the accounts of the inspector-general, for the same three years, was 4,572,000*l.* Of the actual value of British produce and manufactures exported, which usually constitutes about two-thirds of the total export, we have more correct information. By an act passed in 1798, and revived in 1802, called the convoy act, the exporters were required to declare the real value of British manufactures exported, in order to ascertain the amount of duty chargeable thereon; and from these declarations, the actual value of British produce and manufactures exported has been ascertained as follows:

The extent of shipping employed in commercial intercourse at this period, will be seen in the following account of the number of vessels which belonged to the several ports of the British empire, on the 30th September 1805.

	Ships.	Tons.	Men & Boys
England - - -	14,790	1,799,210	117,668
Jersey & Guernsey	185	16,528	2,011
Isle of Man - -	404	9,050	2,336
Scotland - - -	2,581	210,295	15,160
Ireland - - -	1,067	56,806	5,073
The Plantations -	3,024	190,953	15,407
	<u>22,051</u>	<u>2,283,442</u>	<u>157,712</u>

The commerce of Great Britain with *Ireland*, has increased with the improvement of that country, particularly since the year 1780, when a more liberal system of policy was adopted with respect to the foreign trade of Ireland. The imports from thence consist chiefly of butter, beef, pork, bacon, lard, tallow, cattle, hides, feathers, starch, rape-seed, linens, linen-yarn, woollen-yarn, pearl-shells, copper-ore, and a few other articles of less importance. The exports are coals, ironmongery and hardware, hoops for barrels, beer, cyder, dried cod, herrings, chiefly from Scotland, earthenware, bottles and window-glasses, refined sugar, hops, lead, tin-plates, sail-cloth, cabinet-ware, wearing apparel, apothecaries-ware, books and stationery, painters' colours, hats, haberdashery, woollen, cotton, and silk manufactures of all kinds; with rum, brandy, geneva, wines, groceries, drugs, dye-stuffs, flax and hemp, raw and thrown silks, and other foreign produce.

Years.	Imports.	Exports.
1798	£ 2,735,686	£ 2,974,363
1799	2,770,731	2,086,986
1800	2,312,824	3,741,499

Considerable endeavours have been made to improve the manufactures of Ireland, but with little success, except in the linen manufacture, which probably proceeds from the want of sufficient capital, and from the facility with which British manufactures can be procured at a very small additional expence; the latter will, therefore, for a long time, continue to constitute a large proportion of the imports of Ireland.

Value of British manufactures exported from Great Britain to Ireland.

In 1791	£ 1,470,972	In 1796	£ 1,781,789
1792	1,511,844	1797	1,310,996
1793	1,055,276	1798	1,657,954
1794	1,281,316	1799	2,405,999
1795	1,612,270	1800	1,787,966

The trade between Great Britain and *Russia* has been considered highly beneficial to both countries; to *Russia* in point of profit, and to Great Britain, as supplying articles essential to the support of its navy. The capital employed must be much greater than formerly, from the increased value of the principal articles; and the balance of trade, which is consider-

ably in favour of Russia, is paid by means of the commercial transactions between Great Britain and other countries. The articles imported are iron, hemp, flax, tallow, pot-ashes, deals, and lath-wood, coarse linens, hog's bristles, &c. The exports are principally broad-cloths and woollen stuffs, refined sugar, cotton, lead, tin, iron and steel ware, earthen ware and glass, coals, alum, salt, horses, London porter, with articles of less importance.

Years.	Imports.	Exports.
1800	£ 2,382,098	£ 1,025,335
1801	2,246,877	919,843
1802	2,182,430	1,376,399

The total number of vessels that entered inwards from Russia, and that cleared out for that country from Great Britain in three years, ending with 1806, was as follows:

Years.	Inwards.		Outwards.	
	British.	Foreign.	British.	Foreign.
1804	830	29	558	53
1805	961	14	927	52
1806	1106	21	677	32

The trade to *Denmark* and *Norway*, though of ancient date, is not of very great extent; the imports consist chiefly of timber and corn; and the exports, of West India produce and other foreign merchandize; the quantity of British manufactured goods which those countries take being of small amount.

Years.	Imports.	Exports.
1800	£ 241,563	£ 540,698
1801	208,794	416,475
1802	155,672	537,517

The total number of vessels which entered inwards from Denmark and Norway, in the year 1806, was 1607, of which 529 were British ships: the total number which cleared outwards was 1690, of which 790 were British.

The trade with *Sweden*, which is carried on chiefly in ships of that country, has not varied materially in its extent during the last twenty years. The imports consist chiefly of iron of a superior quality, pitch, tar, deal boards, and sail-cloth. The exports are principally colonial produce.

Years.	Imports.	Exports.
1800	£ 309,280	£ 78,840
1801	295,645	111,254
1802	327,350	108,296
1803	288,651	98,045

The total number of vessels which entered inwards from Sweden, in the year 1806, was 353, of which 187 were British ships: the total number which cleared outwards was 362, of which 142 were British.

The imports from *Prussia*, consist of all kinds of grain, hemp, flax, madder, linseed, goose-quills, bristles, pearl-ashes, mill-stones, and timber of various descriptions. The exports are chiefly alum, copperas, coals, beer, salt, wrought brass and iron, lead, tin plates, earthen-ware, glass, woollen and cotton goods, some cotton yarn, India goods, raw and refined sugar, drugs, dye-stuffs, pepper and other spices, coffee, rum, tobacco, &c.

Years.	Imports.	Exports.
1800	£ 1,340,904	£ 794,452
1801	1,387,149	660,739
1802	1,057,602	1,071,896
1803	831,225	1,916,502

The total number of vessels which entered inwards from

Prussia in the year 1805 was 1946, of which 837 were British ships: the total number which cleared outwards was 1627, of which only 482 were British. In 1806 the total numbers were much less, in consequence of Prussia being involved in the war.

The trade with *Germany* had not experienced any considerable variation with respect to its extent, from the commencement of the last century, till on the extension of the war with France in 1794, it suddenly became the channel through which the principal part of the continent received the goods they had before obtained direct from Great Britain. The following account of exports to Germany shews the rapid increase of trade with that country during the war.

Years.	British Manufactures.	Foreign Merchandize
1793	£ 718,474	£ 1,764,221
1794	1,634,530	4,308,695
1795	1,760,133	6,311,876
1796	1,591,810	6,582,179
1797	1,964,967	6,419,587
1798	2,042,774	8,646,691
1799	2,032,567	6,640,729
1800	4,364,120	8,300,470
1801	4,928,617	6,186,687

The total number of vessels which entered inwards in the several ports of Great Britain from Germany (including *Hamburg*) and which cleared outwards for that country, was as follows:

Years.	Inwards.		Outwards.	
	British.	Foreign.	British.	Foreign.
1793	217	54	292	77
1794	258	108	443	152
1795	259	222	257	406
1796	347	342	333	415
1797	237	257	314	371
1798	408	113	647	187
1799	409	126	426	181
1800	435	459	574	458

The total number of vessels which entered inwards from Germany (including *Hamburg*) in the year 1806 was 604; the total number which cleared outwards for that country 956.

The imports from *Holland* are butter and cheese in large quantities, geneva, juniper berries, flax, hemp, oak bark, rags, flower-roots and seeds, books, maps and prints. The exports are raw and refined sugars, train oil, copperas, a few cotton goods, some woollen goods, coffee, rice, and foreign merchandize of various kinds: their amount, as follows:

Years.	Imports.	Exports.
1800	£ 972,600	£ 3,208,613
1801	1,025,958	3,496,744
1802	974,537	4,957,997
1803	630,403	1,565,355

The total number of vessels which entered inwards from Holland in the year 1804 was 790, and the number which cleared outwards 521. The number which entered inwards in 1805, was 709; outwards 323; which, from the two countries being at war, were of course nearly all neutral vessels.

France possesses such natural advantages in the produce of its soil, and the convenience of its situation for procuring the commodities of all other countries, that while its manufac-

tures were encouraged, and it retained possessions in the East and West Indies, little inducement remained for commercial intercourse with Great Britain, and even this limited traffic was much impeded by the high duties and prohibitions which mutual jealousy had imposed. In 1786 a more liberal system was adopted by a treaty of commerce, in consequence of which the trade between the two countries increased considerably. In the year 1792, the exports to France amounted to 1,228,166*l.* 3*s.* 9*d.* of which 743,280*l.* 12*s.* 1*d.* was British manufactures, and 484,885*l.* 11*s.* 8*d.* foreign merchandize. In the following year, the trade with France was suspended by war, on the termination of which, in 1802, commissioners were appointed for adjusting the conditions of a new commercial treaty, but its completion was prevented by the renewal of hostilities.

The trade with *Portugal* was formerly a very beneficial branch of our commerce, but has declined very much. The imports consist chiefly of wine, cotton-wool, and indigo, with considerable sums in cash and bullion. The exports are almost wholly British produce and manufactures.

Years.	Imports.	Exports.
1798	£ 700,383	£ 750,918
1799	1,047,054	1,073,411
1800	916,848	1,011,893

The total number of vessels which entered inwards from Portugal in the year 1800 was 340, of which 270 were British vessels. The number which entered inwards in the year 1806 was 468; outwards 332.

The extent of the trade with *Spain*, previous to the war in 1796, will appear from the statement of imports and exports.

Years.	Imports.	Exports.
1792	£ 897,840	£ 794,101
1793	485,872	476,726
1794	748,546	634,554
1795	992,853	437,830
1796	809,881	546,126

The year 1806 being a year of war, the trade with Spain was of course confined to neutral vessels: the number which entered inwards was 222, and the number which cleared outwards 126.

The *Mediterranean trade* was subject to much interruption during the war which began in 1793, in consequence of which many of the goods usually imported from Venice and Italy were brought over-land through Switzerland and Germany to Hamburgh and Tonningen to be shipped for England. The Turkey and Levant trade was formerly one of the principal branches of English commerce, but it is now of much less importance. The chief articles imported, are cotton-wool, mohair, goats' hair, opium, senna, and other drugs, galls, madder, vallonea, and other dye-stuffs, currants, figs, raisins, goat skins, and box-wood; raw silk was formerly a principal article, but very little is now brought from Turkey, that of Italy being much superior. The exports consist of lead, tin-plates, wrought and cast iron, hardware, a considerable number of watches, some cotton goods, and a few woollen goods, India piece goods, coffee, sugar, cinnamon, cloves, pimento and other spices. The extent of the different branches of the Mediterranean trade will appear from the following statements.

GIBRALTAR and the STREIGHTS.

Years.	Imports.	Exports.	Ships inward.	Ships outward.
1799	£ 62,902	£ 358,784	47	50
1800	35,605	294,558	20	43
1801	24,887	302,971	19	51
1802	21,792	530,537	32	48
1803	23,112	487,699	17	48
1804	33,860	560,399	27	62
1805	42,919	183,824	19	59

In the year 1806, the number of vessels which entered inwards was 24, outwards 83.

ITALY.

Years.	Imports.	Exports.	Ships inward.	Ships outward.
1799	£ 224,607	£ 367,173	69	81
1800	411,765	587,530	115	113
1801	165,042	378,007	44	94
1802	804,329	2,048,784	127	248
1803	748,020	656,607	182	74
1804	268,029	359,854	76	126
1805	393,517	507,535	106	117

In the year 1806, the number of vessels which entered inwards was 90, outwards 61.

MALTA.

Years.	Imports.	Exports.	Ships inward.	Ships outward.
1801	£ 11,448	£ 88,735	10	14
1802	16,698	12,023	36	4
1803	8,922	133,629	22	15
1804	32,913	114,031	20	23
1805	9,304	127,515	6	12

In the year 1806, the number of vessels which entered inwards was 26, outwards 26.

MINORCA.

Years.	Imports.	Exports.	Ships inward.	Ships outward.
1800	£ 13,500	£ 12,246	19	5
1801	6,768	36,130	16	15
1802	22,106	21,478	25	5

In the year 1803, the trade with Minorca ceased, from its having been restored to Spain.

TURKEY and LEVANT.

Years.	Imports.	Exports.	Ships inward.	Ships outward.
1799	£ 33,091	£ 226,078	3	13
1800	199,773	166,804	19	6
1801	141,137	172,198	9	10
1802	182,424	180,000	20	18
1803	175,427	155,369	27	9
1804	148,277	81,625	16	1
1805	103,590	135,411	22	8

In the year 1806, the number of vessels which entered inwards was 23, outwards 3.

The articles imported from the coast of *Africa* into Great Britain are gum arabic, gum sandarach, and senegal, camwood, red-wood, ebony, ivory, a few ostrich feathers, and some skins; their amount in the year 1800 was 82,280*l.* 8*s.* 8*d.* The exports have hitherto been of far greater value,

being principally intended for the purchase of slaves for the West Indies. They consisted of bugles, cowries, spiritous liquors, a great number of guns and cutlasses, gunpowder, wrought brass, copper and iron, glass, earthen ware, rice, groceries, apothecaries' ware, woollen, cotton, and linen goods, and large quantities of India piece goods. The total official value in the year 1800 was 1,017,365 *l.* 11 *s.* 5 *d.* of which 521,922 *l.* 19 *s.* 11 *d.* was British merchandize. The abolition of the infamous traffick in human beings, must cause a great revolution in the trade to this part of the world, as it appeared in the year 1789 that about 38,000 of the inhabitants of Africa were annually carried away in British ships for supplying the colonies with slaves, which of course employed a considerable number of vessels. The number of ships that cleared out from Great Britain for Africa, in the year 1804, was 176.

The *East India* trade furnishes a remarkable instance of an extensive branch of commerce carried on successfully in the hands of an exclusive company, while most other commercial monopolies have made very small profits, and generally soon expired. The trade to India, however, since the immense territorial acquisitions of the English in that part, can no longer be considered as a mere commercial adventure, as it is now in a great measure a business of agency, for transmitting to Europe the fortunes acquired by British individuals in the East. The quantity of merchandize brought from thence, consequently greatly exceeds the value of the exports to India. The latter consists chiefly of woollens, metals, and naval and military stores, the remaining articles being of trifling amount in comparison, and almost wholly for the use of Europeans, as the natives are peculiarly attached to the use of their own produce and manufactures. The exports to China include a considerable amount in bullion, the other articles are woollen cloths and camblets, lead, and tin; the articles exported in private trade are, skins and furs, glass of various descriptions, jewellery, toys, and watches, cuttings of cloth, a very few woollens, some cutlery and hard ware, and silver. The amount of the company's exports to India and China, will appear from the following statements.

INDIA.

Season.	Merchandize, or Manufacture.	Metals.	Stores.
1781	£ 200,808	£ 157,614	£ 163,878
1782	123,834	183,356	133,773
1783	95,251	122,855	77,237
1784	92,205	93,806	55,256
1785	74,683	80,152	104,226
1786	122,709	97,899	85,179
1787	108,388	137,194	153,603
1788	119,449	99,028	152,587
1789	80,184	273,104	100,435
1790	75,141	191,944	120,525
1791	86,680	124,889	108,560

CHINA.

Season.	Merchandize, or Manufacture.	Metals.	Stores.	Bullion.
1781	£ 129,179	£ 10,349	£ 2,206	
1782	94,992	9,416	1,717	
1783	113,763	4,579	1,743	
1784	146,744	27,835	2,904	
1785	224,612	37,989	7,503	724,317

Season.	Merchandize or Manufacture.	Metals.	Stores.	Bullion.
1786	202,023	35,535	6,972	749,833
1787	323,107	38,046	7,289	646,798
1788	335,392	59,208	6,598	489,192
1789	354,717	107,995	7,769	787,078
1790	431,385	105,707	4,081	532,705
1791	486,993	99,448	4,000	422,098

The imports from the East Indies consist of Bengal piece-goods, coast and Surat piece-goods, Bengal and China raw-silk, tea, pepper, saltpetre, nankeen cloth, china, wrought silks, a small quantity of china-ware, sugar, coffee, indigo, and various drugs. The total amount of the imports, on the company's account, and in private trade, according to the official rates of the inspector-general's office, was as follows:

Years.	Import.	Years.	Import.
1781	£ 2,526,339	1793	£ 3,499,023
1782	626,319	1794	4,458,475
1783	1,301,495	1795	5,760,810
1784	2,996,652	1796	3,372,689
1785	2,703,940	1797	3,942,384
1786	3,156,687	1798	7,626,930
1787	3,430,868	1799	4,284,805
1788	3,453,897	1800	4,942,275
1789	3,364,545	1801	5,424,441
1790	3,149,870	1802	5,794,906
1791	3,698,713	1803	6,348,887
1792	2,701,547	1804	5,214,622

But a more accurate idea of the real value of the imports from the East Indies, may be formed from the annual amount of the company's sales, which was

In 1801	£ 7,595,181	In 1803	£ 6,042,526
1802	6,626,347	1804	5,866,073

The *West India* trade is, in some respects, the most important branch of the commerce of Great Britain; as on the colonial produce which it supplies, much of the trade with different parts of Europe chiefly depends. The value of the British West India produce from the old islands, imported into Great Britain, on a medium of four years, preceding the 5th of January 1796, according to the current prices during that period, was estimated, exclusive of the duties, at about 6,800,000 *l.* per annum. This sum is not wholly a return for goods exported, a part of it must be considered as remittances of the property of persons who possess estates in the West Indies; but who are wholly or occasionally resident in England; and of persons who have lent money on mortgage or otherwise in the West Indies, and receive their interest from the sale of the produce.

Official Value of Imports from the West Indies.

Years.	British West Indies.	Conquered Islands.	Total.
1801	£ 6,759,617	£ 4,105,839	£ 10,865,456
1802	7,293,316	2,699,504	9,992,820
1803	5,786,432	362,014	6,148,436

The value of the British West India islands, in a commercial view, will be very conspicuous from the following statement of the total quantities of sugar, rum, coffee, and cotton-wool, exported from them.

Years.	Sugar. Cwt.	Rum. Galls.	Coffee. Cwt.	Cotton Wool. lbs.
1793	2,129,750	4,927,051	92,016	9,173,583
1794	2,141,921	5,597,520	141,007	8,473,175
1795	1,743,939	4,173,734	144,800	11,675,495
1796	1,816,584	5,567,754	94,086	8,854,413
1797	1,636,631	4,279,164	114,947	6,918,153
1798	2,015,602	6,224,076	165,075	7,909,832
1799	2,628,470	6,270,449	132,259	7,529,881
1800	2,413,997	6,231,225	180,374	10,611,349
1801	2,959,958	8,148,571	199,359	11,261,014
1802	3,463,366	8,676,381	230,148	8,799,891
1803	2,880,479	8,781,496	173,883	5,650,615

To Hudsons bay	38,061	0	9
Newfoundland	219,458	5	11
Canada - - -	460,155	13	3
New Brunswick	81,230	15	4
Nova Scotia -	177,083	17	10

Total £ 975,989 13 1

The total number of vessels which entered inwards from the West Indies, in the year 1804, was 721, containing 204,411 tons, and navigated by 12,119 seamen. The number of vessels which cleared outwards was 790. The value of British produce and manufactures exported to the British plantations in the West Indies, exclusive of the Conquered islands, was 3,408,232 *l*.

The trade with the United States of America, has rapidly advanced to very considerable importance; and Great Britain now supplies them with commodities to a far greater amount, than in the most favourable years previous to their independence, although the number of British ships employed is considerably less. In the year 1789 the number of British vessels which entered inwards in this trade was 253, the number outwards 358; in the year 1799, the number which entered inwards was only 42, the number outwards 57.

Years.	Imports.	Exports.
1798	£ 1,782,720	£ 5,580,370
1799	1,818,941	7,056,558
1800	2,357,922	6,885,507

The total number of vessels which entered inwards from the United States, in the year 1806, was 561, of which 53 were British; the total number which cleared outwards was 575, of which only 39 were British.

The remaining possessions of Britain in North America, being countries not very fertile or fully inhabited, the trade with them is not of very great extent. The following statement of the exports to those parts in the year 1800, will, however, shew that the trade is well worth preserving, independent of the consideration that it is the means of procuring articles of much importance in other branches of commerce.

With respect to the general balance of trade, or the ultimate profit which Great Britain derives from its commerce with all other countries, Mr. Irving, the inspector-general of imports and exports, to whom the public have, for many years, been indebted for the judicious arrangement and explanation of the official documents relating to foreign trade, has justly remarked, that there are perhaps few questions to which the human attention can be directed more difficult to form an opinion upon, from the variety of considerations, and the vast statements with which it is connected, and also from the materials on which conclusions are to be formed, being in some instances defective; he has, however, stated it as his opinion, that the balance of trade in favour of Great Britain, according to the true value of the goods exported and imported, amounted on a medium of the four years preceding 1796, to upwards of 6,500,000 *l*. per annum, exclusive of the profits derived from the East and West India trades, which he estimated at upwards of 400,000 *l*. per annum; and exclusive of the profits derived from the fisheries.

An accurate view of the progress and extent of commerce in all the European states, would furnish much information; but with respect to several, no authentic particulars of this kind have been made public, and the foreign trade of others has been so entirely turned out of its usual channels since the commencement of the war of the French revolution, that any account of its present state would be very incomplete and unsatisfactory.

With respect to domestic commerce, we may observe, that the king is the arbiter of it; as it pertains to his prerogative to establish public marts, as markets and fairs, to regulate weights and measures, and to give money, which is the universal medium of commerce, authority and currency.

A great part of the foreign commerce of England is now carried on by collective companies: some incorporated by the king's charters, with an exclusive privilege, as the East India company; others only private associations, as the Turkey and Hamburg companies. See COMPANY.

Company

COMPANY, a collective term, understood of several persons assembled together in the same place, or with the same design. See SOCIETY.

The word is formed of the French *compagnie*, and that of *companion* or *companies*, which, Chifflet observes, are found in the Salic law, tit. 66. and are properly military words, understood of soldiers, who, according to the modern phrase, are comrades, or *meis-mates*, i. e. lodge together, eat together, &c. of the Latin *cum*, *with*, and *panis*, *bread*. It may be added, that in some Greek authors under the Western empire, the word *κμπανια* occurs in the sense of *society*.

COMPANY, in *Commerce*, is an association of several merchants, or others, who unite in one common interest, and contribute by their stock, their counsel, and study, to the setting on foot, or supporting, of some lucrative establishment.

Though *company* and *society*, or fellowship, be in effect, the same thing, yet custom has made a difference between them; *society*, or partnership, being understood of two, or three dealers, or not many more; and *company* usually of a greater number. See SOCIETY.

A second difference between *companies* and *societies* is, that the first, especially when they have exclusive privileges,

cannot be established without the concession of the prince; and need letters patent, charters, &c. Whereas, for the latter, the consent of the members, fixed and certified by acts and contracts, and authorized by bye-laws, is sufficient.

The several professions and trades exercised in the city of London, being incorporated into distinct fraternities, governed by their particular laws, a tabular view of them may not be unacceptable.

The abstract of their incorporations, and particular privileges, is taken from the records of the Tower, &c. and from the *Firma-Burgi* of Madox, the king's historiographer; the account of their charities from those eminent historians Stow and Strype; and the fines of the liverymen on admission, are taken from the returns to the clerk of the parliament, and the scrutiny-books made after the several polls for the magistrates and representatives of the city.

The companies are here placed according to their precedence, beginning with the twelve principal ones, of one or other of which the lord mayors have generally made themselves free at their election, if they were not so before; for they are not only the oldest, but the richest, many of them having had the honour of kings and princes to be their members, and the apartments of their halls being fit to entertain a monarch.

Companies.	Halls.	Incorporated A. D. by	Livery fines <i>l. s. d.</i>	Charitable Gifts paid yearly, and Privileges, &c. <i>l.</i>
1 Mercers	Cheapside	Richard II.	1393 2 13	3000 Exclusive of 20 per cent. paid yearly to the widows of subscribing clergymen during life, pursuant to a proposal accepted in 1698, when they settled a fund of 14,000 <i>l.</i> a year for that purpose.
2 Grocers	Poultry, Groc. alley	Edward III.	1345 20 0 0	700
3 Drapers	Throgmorton street	Henry VI.	1439 25 0 0	4000
4 Fishmongers	Thames-street	Henry VIII.	1536 13 6 8	800
5 Goldsmiths	Foster-lane	Richard II.	1393 20 0 0	1000 They had a privilege from Ed. IV. to inspect, try, and regulate all gold and silver wares throughout the kingdom, and to punish all workers in either that was adulterated.
6 Skinners	Dowgate-hill	Edward III.	1327 15 0 0	700
7 Merchant Taylors	Threadneedle-street	Edward IV.	1466 20 0 0	2000 They were once styled taylors and linen armourers.
8 Haberdashers	Maiden-lane	Henry VI.	1407 25 0 0	3500 Were anciently styled Milaners, because they dealt in most that came from Milan.
9 Salters	Swithin's-lane	Q. Elizabeth	1558 20 0 0	500
10 Ironmongers	Fenchurch-street	Edward IV.	1464 31 10 0	1800 In 1724, Mr Betton, a Turkey merchant, left 26,000 <i>l.</i> in trust; one moiety of the profits of it to be always applied to the ransom of British captives from Moorish slavery; the other for the poor of the company, and to the charity-schools in its city and its liberty.
11 Vintners	Thames-street	Henry VI.	1437 31 13 4	600
12 Clothworkers	Mincing-lane	Edward IV.	1482 31 10 0	1400

Companies	Halls.	Incorporated A. D. by	Livery fines	Charitable Gifts, paid yearly, and Pri- vileges, &c.
			<i>l. s. d. l.</i>	
Dyers	Elbow-lane	Edward IV. 1472	15 0 0	
14 Brewers	Addle street	Henry VI. 1438	6 13 4	
15 Leatherfellers	Little St. Helens	Henry VI. 1442	20 0 0	* Hen. VII. made their wardens in- spectors of sheep, lamb, and calves leather throughout the kingdom.
16 Pewterers ‡	Lime-street	Edward IV. 1474	20 0 0	‡ By act of Parl. 25 Hen. VIII. their wardens had the inspection of pewter through- out England.
17 Barber-surgeons †	Monkwell-street	Edward IV. 1461	10 0 0	† In the reign of Hen. VIII. the sur- geons of this company, then but 19, were exempted by parliament from ward and parish offices, and from military service. They were incorporated separately by 18 Geo. II. cap. 15. and the company of surgeons had an elegant hall in the Old Bailey, with a theatre for the dissection of human bodies. They now form a royal college, and their house is in Lincoln's Inn fields.
18 Cutlers	Cloak-lane	Henry V. 1417	10 0 0	
19 Bakers	Harp-lane	Edward II. 1307	10 0 0	
20 Wax-chandlers	Maiden lane	Richard III. 1483	5 0 0	
21 Tallow-chandlers	Dowgate-hill	Edward IV. 1463	15 0 0	
22 Armourers §	Coleman-street	Henry VI. 1423	15 0 0	§ The brasiers are united to this com- pany.
23 Girdlers	Basinghall-street	Henry VI. 1449	5 0 0	Q. Elizabeth incorporated the pin- ners and wire-drawers with them.
24 Butchers †	Pudding-lane	James I. 1615	11 11 0	† This is an ancient fraternity; of which we have an account in the reign of Henry II. A. D. 1180.
25 Sadlers	Cheapside	Edward I. 1200	10 0 0	
26 Carpenters	London-wall	Edward III. 1344	8 0 0	
27 Cordwainers	Distaff-lane	Henry IV. 1410	10 0 0	
28 Painter-stainers	Little Trinity-lane	Q. Elizabeth 1582	14 0 0	
29 Curriers	Near Cripplegate	James I. 1605	9 13 4	
30 Masons	Basinghall-street	Charles II. 1677	5 0 0	
31 Plumbers	Near Dowgate-hill	James I. 1611	10 0 0	
32 Innholders	Elbow-lane	Henry VIII. 1515	10 0 0	
33 Founders **	Lothbury	James I. 1614	8 0 0	** All brass weights made in London, or three miles from it, must be siz- ed with the company's standard, and have their mark; the averdu- pois to be sealed at Grub-hall, and the troy at goldsmith's hall. And the company are empowered by charter, to view and search all brass weights, and brass and copper wares made within the said district.
34 Poulcers	No hall	Henry VII. 1504	10 0 0	
35 Cooks	Hall burnt	Edward IV. 1480	10 0 0	
36 Coopers	Basinghall-street	Henry VII. 1501	15 0 0	
37 Tylers and bricklayers	Leadenhall-street	Q. Elizabeth 1568	12 0 0	
38 Bowyers	No hall	James I. 1620	8 0 0	
39 Fletchers ¶	St. Mary Axe	No charter	10 0 0	¶ It is only a company by prescription.
40 Blacksmiths	Lambeth-hill	Q. Elizabeth 1577	8 0 0	
41 Joiners and cielers	Thames-street	Q. Elizabeth 1569	8 0 0	
42 Weavers	Basinghall-street	Henry II. 1155	6 0 0	
43 Woolmen	No hall	No charter	No livery; but they have a master, 2 wardens, and 11 assistants. They are only a company by prescription, yet supposed to have com- menced with the wool-trade.	
44 Scriveners	No hall	James I. 1616	5 0 0	
45 Fruiterers	No hall	James I. 1605	5 0 0	
46 Plasterers	Addle street	Henry VII. 1501	8 0 0	
47 Stationers ††	Ludgate-street	Philip & Mary 1557	20 0 0	†† This company, which also includes booksellers, letter-founders, printers, and book-binders, have a stock which is employed in printing almanacks, primers, psalters, school-books, &c. of which they have the sole privilege, by virtue of a grant from the crown. This stock consists of shares, which are distributed in different proportions among those who have fined for, or served the office of renter-wardens: whose shares, if they die married, devolve to their widows. They pay above 200 <i>l.</i> a year in pensions and other charities. They are likewise trustees for the disposal of the considerable legacies of Mr. William Bowyer, a learned printer, (who died Nov. 18, 1778) consisting of 30 <i>l.</i> a year to the most learned journeyman that can be met with; and 180 <i>l.</i> a year in annuities of 20 <i>l.</i> each to nine necessitous printers of sixty- three years of age or upwards; besides other charities.
48 Broderers	Gutter-lane	Q. Elizabeth 1591	5 0 0	
49 Upholders	No hall	Charles I. 1627	4 10 0	
50 Musicians	No hall	James I. 1604	10 0 0	

Companies.	Halls.	Incorporated by	A. D.	Livery fines. <i>l. s. d.</i>	Charitable Gifts, paid yearly, and Privileges, &c.
51 Turners	College-hill	James I.	1604	8 0 0	
52 Basket-makers	No hall	No charter			No livery; yet a company by prescription, governed by 2 wardens and 48 assistants, with this motto to its arms, <i>Let us love one another.</i>
53 Glasiers	No hall	Charles I.	1637	3 0 0	The glass painters are incorporated with them.
54 Horners	No hall	Charles I.	1638		No livery; yet they have a master, 2 wardens, and 9 assistants, with a warehouse in Spitalfields; where they divide in lots, among themselves, such horns as are bought up by their members in Leadenhall and other markets: And in 1465, they obtained an act of parliament that none should be exported, but such as they refused.
55 Farriers	No hall	Charles II.	1673	5 0 0	
56 Pavours	No hall	No charter			No livery; yet it is a fellowship by prescription, with 3 wardens, and 25 assistants.
57 Loriners	London-wall	Q. Anne	1712	10 0 0	
58 Apothecaries	Blackfryars	James I.	1617	16 0 0	They are exempt from ward and parish-offices, and have a spacious physic-garden at Chelsea; which in 1721 was granted to the company for ever by Sir Hans Sloane, bart. the lord of the manor, on condition of their paying a quit-rent of 5 <i>l.</i> and continuing it always as a physic-garden, and of presenting every year to the Royal Society fifty samples of different sorts of plants, there grown, till they amount to two thousand.—The latter of these conditions hath been long since more than completed. This is what may be called a trading company.
59 Shipwrights	No hall	James I.	1605		No livery; yet they have a master, 2 wardens, and 16 assistants.
60 Spectacle-makers	No hall	Charles I.			No livery; yet have a master, 2 wardens, and 15 assistants.
61 Clock-makers	No hall	Charles I.	1632	10 0 0	
62 Glovers	No hall	Charles I.	1638	5 17 4	
63 Comb-makers	No hall	Charles I.	1636		No livery; yet they have a master, 2 wardens, and 13 assistants.
64 Felt-makers	No hall	James I.	1604	5 0 0	
65 Framework-knitters	Red cross-street	Charles II.	1663	10 0 0	
66 Silk-throwers	No hall	Charles I.	1620		No livery; yet have a master, 2 wardens, and 20 assistants.
67 Silkmen	No hall	Charles I.	1631		No livery; yet have a governor, and 20 assistants.
68 Carmen	have no hall, nor charter, nor livery; but are a fellowship by act of common council, with the title of Free Carmen of the city of London, and have a master, 2 wardens, and 41 assistants, under the direction of the lord mayor and aldermen. The carts that belong to this fellowship, which are betwixt 4 and 500, are, by an act of common council, subjected to the rule of the president and governors of Christ's Hospital; to whom the owner of every cart pays 17 <i>s.</i> 4 <i>d.</i> a year for a licence to work it, and every cart is brought to the hospital to have a number in brass put upon it.				
69 Pin-makers	No hall	Charles I.	1636		No livery; yet have a master, 2 wardens, and 18 assistants.
70 Needle-makers	No hall	O. Cromwell	1656	5 5 0	
71 Gardeners	No hall	James I.	1616		No livery; yet have a master, 2 wardens, and 18 assistants.
72 Soap makers	No hall	Charles I.	1630		No livery; yet have a master, 2 wardens, and 18 assistants.
73 Tin-plate-workers	No hall	Charles II.	1670	10 0 0	
74 Wheelwrights	No hall	Charles II.	1670	15 15 0	
75 Distillers	No hall	Charles I.	1638	13 6 8	
76 Hatband-makers	No hall	Charles I.	1638		Incorporated with the company of needle-makers.
77 Patten-makers	No hall	Charles II.	1670	6 0 0	
78 Glass-sellers and look- ing-glass-makers }	No hall	Charles II.	1664	5 0 0	
79 Tobacco-pipe-makers	No hall	Charles II.	1663		No livery; yet have a master, 2 wardens, and 18 assistants.
80 Coach and harness-makers	Noble-street	Charles II.	1677	10 0 0	
81 Gunsmiths	No hall	Charles I.	1638	10 0 0	
82 Gold and silver wire-drawers	No hall	James I.	1623		No livery; yet have a master, 2 wardens, and 18 assistants.
83 Long-bow-string-makers	No hall	No charter			No livery; yet a company by prescription, and

Companies	Halls.	Incorporated A. D. by	Livery fines.	Charitable Gifts paid yearly, and Pri- vileges, &c.
84 Card-makers	No hall	Charles I.	1629	No livery; yet have a master, 2 wardens, and 18 assistants.
85 Fan-makers	No hall	Q. Anne	1709	No livery; yet have a master, 2 wardens, and 20 assistants.
86 Woodmongers were a company incorporated with the carmen by K. James I. 1605, but surrendered their charter in 1668; by an act of common council in 1694, they obtained a privilege of keeping 120 carts, exclusive of the number kept by the carmen, <i>extinct</i> .				
87 Starch-makers, <i>extinct</i>	No hall	James I.	1622	
88 Fishermen, <i>extinct</i>	No hall	James II.	1687	
89 Parish-clerks	Wood-street	Henry III.	1233	By a decree of the Star chamber court in 1625, they obtained a privilege to keep a press in their hall, for printing the weekly bills of mortality, by a person appointed by the archbishop of Canterbury. They are, by their charter, to make a report of all the weekly christenings and burials in their several parishes every Tuesday, and they have a master, 2 wardens, and 17 assistants.
90 Porters, are another fellowship, without hall, or livery; consisting of tackle and ticket-porters. They were constituted a fraternity by act of common council in 1646, with a power of annually chusing among themselves twelve rulers, being six of each denomination. However, the court of lord mayor and aldermen have reserved to themselves a power of appointing one of their own body, as the chief judge in all controversies. One very laudable custom of the master tackle-porters is, that such of their brethren as happen to be disabled from working, receive their share of all profits, as if actually in business, during life.				
91 The watermen, wherry-men, and lightermen of this city and neighbouring places, were by act of K. William III. constituted a society, or company, under the direction of the lord mayor and aldermen. They are to furnish 1000 men for the navy, upon demand by the admiralty. They have a hall at Coal Harbour, near the Thames; and pay to their poor about 800 <i>l.</i> a year; chiefly raised by ferries over the Thames on Sunday.				
N. B. The company of Surgeons, Parish-clerks, Porters and Watermen, have not the privilege of making their members freemen of the city of London.				

From the foregoing list, it appears on the whole, that there are ninety-one companies, forty-eight halls, and that the number of liverymen, according to the most exact account that could be procured, in 1779, was 8954, but this number is variable. The sums of money yearly distributed in charity by only twenty-three of the companies, amounts to more than 23,655 *l.*; and if but forty pounds each be annually given by the remaining sixty-eight companies, the whole will much exceed 26,375 *l.* per annum.

COMPANY seems more peculiarly appropriated to those grand associations, set on foot for the commerce of the remote parts of the world; as the English and Dutch East India company, South Sea company, Mississippi company, &c.; the rise and establishment of which, we shall here set before the reader.

However injurious companies with joint-stock, and incorporated with exclusive privileges, may, at this time, be reckoned to the nation in general; it is yet certain that they were the general parent of all our foreign commerce: private traders being discouraged from hazarding their fortunes in foreign commerce, until the method of traffic had been first settled by joint-stock companies. From this principle it is, that we find several nations that are now endeavouring to improve their trade, and to establish or increase marine power, by the means of joint-stock companies.

But since the trade of this kingdom, and the number of traders have increased, and the methods of assurance of shipping and merchandise, and the navigation to all parts of the known world have become familiar to us; these companies, in the opinions of most men, have been looked upon in the light of monopolies: their privileges have therefore been lessened from time to time, in order to favour a free and general trade; and experience has shewn, that the trade of the nation has advanced, in proportion as monopolies have been discouraged. When companies do not trade upon a joint-stock, but are obliged to admit any person properly qualified, upon paying a certain fine, and

agreeing to submit to the regulations of the company, each member trading upon his own stock, and at his own risk, they are called *regulated companies*. When they trade upon a joint-stock, each member sharing in the common profit or loss in proportion to his share in this stock, they are called *joint-stock companies*. Such companies, whether regulated or joint-stock, sometimes have, and sometimes have not, exclusive privileges. Regulated companies resemble, in every respect, the corporations of trades, so common in the cities and towns of all the different countries of Europe; and are a sort of enlarged monopolies of the same kind. As no inhabitant of a town can exercise an incorporated trade, without first obtaining his freedom in the corporation; so in most cases no subject of the state can lawfully carry on any branch of foreign trade, for which a regulated company is established, without first becoming a member of that company. Of companies of this kind we have had, or still have, in Great Britain, the Hamburg company, the Russia company, the Eastland company, the Turkey company, and the African company. Regulated companies, as sir Joshua Child has observed, though they had frequently supported public ministers, had never maintained any forts or garrisons in the countries to which they traded; whereas joint-stock companies frequently had. And in reality, says Dr. Smith, (*Wealth of Nations*, vol. iii. p. 116.) the former seem to be much more unfit for this sort of service than the latter; partly, because the directors of a regulated company have no particular interest in the prosperity of the general trade of the country, for the sake of which such forts and garrisons are maintained; whereas the private interest of the directors of a joint-stock company, is connected with the prosperity of the general trade of the company, and with the maintenance of the forts and garrisons which are necessary for its defence; and partly, because the directors of the latter company have always the management of a large capital, the joint-stock of the company, a part of which they may frequently employ, with propriety, in building, repairing, and maintaining such necessary forts and garrisons; whilst

the directors of a regulated company, having the management of no common capital, have no other fund to employ in this way, but the casual revenue arising from the admission fines, and from the corporation duties imposed upon the trade of the company.

Joint-stock companies, established either by royal charter or by act of parliament, differ, in several respects, not only from regulated companies, but from private copartnerships. 1st. In a private copartnership, no partner, without the consent of the company, can transfer his share to another person, or introduce a new member into the company. Each member, however, may, upon proper warning, withdraw from the copartnership, and demand payment of his share of the common stock. In a joint-stock company, on the contrary, no member can demand payment of his share from the company; but each member can, without their consent, transfer his share to another person, and thereby introduce a new member. 2dly. In a private copartnership, each partner is bound for the debts contracted by the company to the whole extent of his fortune; whereas, in a joint-stock company, each partner is bound only to the extent of his share. The trade of a joint-stock company is always managed by a court of directors, which is frequently subject, in a variety of respects, to the controul of a general court of proprietors; but these proprietors, being for the most part totally exempted from trouble and from risk, beyond a limited sum, receive contentedly such half-yearly or yearly dividends, as the directors think proper to assign; and many persons are encouraged to become adventurers in joint-stock companies, who would, upon no account, hazard their fortunes in any private copartnership. The directors of such companies being the managers rather of other people's money than of their own, it cannot well be expected, that they should watch over it with the same anxious vigilance with which the partners in a private copartnership frequently watch over their own. Negligence and profusion must always prevail, more or less, in the management of the affairs of such a company. It is upon this account that joint-stock companies for foreign trade have seldom been able to maintain the competition against private adventurers. They have, accordingly, very seldom succeeded without an exclusive privilege, and frequently have not succeeded with one. Without an exclusive privilege, they have commonly mismanaged the trade; with an exclusive privilege, they have both mismanaged and confined it. For other appropriate and just observations on this subject, in its reference to the African company, the Hudson's bay company, the South Sea company, and the East India company, see Smith's *Wealth of Nations*, vol. iii. chap. 1.

When a company of merchants undertake, at their own risk and expence, to establish a new trade with some remote and barbarous nation, it may not be unreasonable to incorporate them into a joint-stock company, and to grant them, in case of their success, a monopoly of the trade for a certain number of years. It is the ancient and most natural way in which the state can recompense them for hazarding a dangerous and expensive experiment, of which the public is afterwards to reap the benefit. A temporary monopoly of this kind may be vindicated upon the same principles upon which a like monopoly of a new machine is granted to its inventor, and that of a new book to its author. But upon the expiration of this term, the monopoly ought certainly to terminate; the forts and garrisons, if it was found necessary to establish any, to be taken into the hands of government, their value to be paid to the company, and the trade to be laid open to all the subjects of the state. Without a monopoly, however, a joint-stock company, as expe-

rience has shewn, cannot carry on any branch of foreign trade. An eminent French author, of great knowledge in matters of political economy, the abbé Morellet, gives a list of 55 joint-stock companies for foreign trade, which have been established in different parts of Europe since the year 1600, and which, according to him, have all failed from mismanagement, notwithstanding they had exclusive privileges. Although he has been misinformed with regard to the history of two or three of them, which were not joint-stock companies, and which have not failed; yet there have been several joint-stock companies, which have failed, and which he has omitted.

The only trades which it seems possible for a joint stock company to carry on successfully without an exclusive privilege, are those, of which all the operations are capable of being reduced to what is called a routine, or to such a uniformity of method as admits of little or no variation. Of this kind is, first, the banking trade; secondly, the trade of insurance from fire, and from sea-risk and capture in time of war; thirdly, the trade of making and maintaining a navigable cut or canal; and fourthly, the similar trade of bringing water for the supply of a great city. To render the establishment of a joint-stock company perfectly reasonable, with the circumstance of being reducible to strict rule and method, two other circumstances ought to concur. First, it ought to appear with the clearest evidence, that the undertaking is of greater and more general utility than the greater part of common trades; and, secondly, that it requires a greater capital than can easily be collected into a private copartnership. In the four trades above-mentioned both these circumstances concur.

The joint-stock companies, says this judicious writer, which are established for the public spirited purpose of promoting some particular manufacture, over and above managing their own affairs ill, to the diminution of the general stock of the society, can, in other respects, scarce ever fail to do more harm than good. Notwithstanding the most upright intentions, the unavoidable partiality of their directors to particular branches of the manufacture, of which the undertakers mislead and impose upon them, is a real discouragement to the rest, and necessarily breaks, more or less, that natural proportion which would otherwise establish itself between judicious industry and profit, and which, to the general industry of the country, is of all encouragements, the greatest and the most effectual.

COMPANY, *African*; sometimes called "Royal African Company," the name of the original institution. The first commercial voyage from England to the coast of Guinea was in 1536, but nothing like a company was formed till the year 1588, when queen Elizabeth granted a patent for ten years to come, to some merchants of Exeter, and other persons for an exclusive trade to the rivers Senegal and Gambia. In 1618, king James I. granted a charter for establishing a joint-stock company; but separate traders continuing to resort to the coast, the company was soon dissolved. Another company was erected by charter in 1631, which met with little success; and in 1651, the parliament granted a charter for five years to the East India company, for trading to the Gold coast in their way to India. The demand for negroes in the West India and American plantations increasing considerably, another exclusive African or Guinea company was incorporated in 1662, at the head of which was the duke of York, joined with many persons of rank and distinction. This company, like those that had preceded it, was unsuccessful, and its charter was soon after revoked by consent of the parties associated in the enterprise; in consequence of which another exclusive company

was incorporated by letters patent in 1672. They raised a capital of 111,000*l.* and improved the trade considerably; but at the revolution, the West India planters joined the separate traders in asserting that they were always best served with slaves when the trade was free to all persons; and exclusive companies, whose privileges had not been sanctioned by parliament, being considered inconsistent with the declaration of rights, the trade became open again; but all private traders were to pay 10 per cent. to the company, towards maintaining the forts and factories on the coast. This contribution was however found insufficient, and in 1730 parliament granted 10,000*l.* for the purpose, which was continued annually till 1744, when, in consequence of the war, 20,000*l.* was granted, and in almost every year since, a sum has been appropriated by parliament to this purpose.

As all the joint-stock companies which had been established for this trade had appeared incompetent to carry it on with advantage, it was in 1750 (23 Geo. II. c. 31.) transferred to a regulated company, the members of which are deemed a body corporate and politic, under the title of *The Company of Merchants trading to Africa*, but are prohibited from trading in their corporate capacity, from having any joint or transferable stock, and from borrowing money under their common seal. Any person intending to trade to Africa, may become free of this company on payment of forty shillings; and out of the monies thus received, a sum not exceeding 800*l.* is allowed for the salaries of clerks and agents at London, Bristol, and Liverpool, the house-rent of their office at London, and all other expences of management, commission, and agency in England. What remains of this sum, after defraying these different expences, they may divide among themselves, as compensation for their trouble, in what manner they think proper. The forts, factories, &c. possessed by the old company on the coast of Africa, are vested in the present company, who continue to receive an annual sum from parliament (generally about 13,000*l.*) for the support of these establishments: the sum granted in the year 1806 was 18,000*l.* For the proper application of this sum, the committee is obliged to account annually to the furst baron of the exchequer, which account is afterwards to be laid before parliament.

The company is under the management of a committee of nine persons, three being chosen for London, three for Bristol, and three for Liverpool, annually. The committee are enjoined to lay an annual account of the application of the money granted to them before parliament.

Although by the 4th of Geo. III. c. 20. the fort of Senegal, with all its dependencies, had been vested in this company, yet in the year following (by the 5th of Geo. III. c. 44.) not only Senegal and its dependencies, but the whole coast from the port of Sallee, in South Barbary, to cape Rouge, was exempted from the jurisdiction of that company, and vested in the crown; the trade to it being declared free to all his majesty's subjects.

Before the establishment of the Royal African company, there had been three other joint-stock companies successively erected one after another, for the African trade. They were all equally unsuccessful. They all, however, had exclusive charters, which, though not confirmed by act of parliament, were in those days supposed to convey a real exclusive privilege.

COMPANIES, English. *The East India Company* was established by charter dated Dec. 31, 1600, by which the earl of Cumberland and 215 other persons were authorized to carry on an exclusive trade to all parts of the East Indies, for 15 years; under the title of "*The Governor and Company of Merchants of London trading to the East Indies.*" They

raised 72,000*l.* in shares of 50*l.* each, and fitted out five ships, which accomplished their first voyage very successfully, in two years and seven months.

Having carried on the trade for about ten years, with different degrees of success, they obtained another charter dated May 31, 1610, by which the company was made perpetual. They had not yet adopted the mode of trading under one joint stock, but carried it on in several co-partnerships and lesser stocks. In 1613 the proprietors of the several separate stocks, united them into one general joint-capital; and notwithstanding some opposition to their trade, both at home, and abroad, they preferred and extended it, having at this time established factories at about twenty different places in India. In a vindication of the East India Company before the privy council, at a subsequent period, among other remarks for shewing the great difficulties attending an East India trade, it was asserted, that although they had a stock of 1,500,000*l.* yet in fifteen years time, viz from 1617 to 1632, their whole profit was no more than 12 and one-half per cent.

In 1637, Charles I. established a new company to trade to China and Japan, but it was soon ruined. The old company likewise from its differences with the Dutch East India company, the encroachments of private adventurers, and other causes, fell into decay, and in 1655 it was dissolved by Cromwell, and the trade laid open. The mischiefs which followed obliged him to re-establish the company about three years after; their joint-stock was now 739,782*l.*, of which only one half, or 369,891*l.* was paid in, and was properly their capital. The total exports of the company in three years, ending with 1660, was 227,820*l.* in bullion, and 23,763*l.* in merchandize. After the restoration, they obtained a new charter from Charles II. dated April 3, 1661. By this charter it appears that the company had not then one sole transferable joint-stock; but that every one, who was free of this company paid a certain sum of money to the company on the fitting out of their fleet, for which he had credit in the company's books, and received his proportionate dividend on the profits of the respective voyage. The whole investments were made by the company in their corporate capacity; but they were not established as an irrevocable corporation, as they might be dissolved on three years notice.

In 1664, the company's stock sold at only 70 per cent., but in consequence of an inquiry into the state of their affairs, the result of which was very favourable, the stock soon got up considerably. New charters were granted in 1669 and 1676, confirming all their privileges. In the latter year, the company having made a considerable profit by their trade, agreed, instead of making a dividend thereof, to add it to their capital stock, so as just to double the same, by which their capital became 730,782*l.* 10*s.* In consequence of the extension and success of their trade, which enabled them to make large dividends, their stock in 1680 sold from 280 to 300 per cent; but these great profits, and the doubtful authority on which they held their exclusive privileges, (not having the sanction of parliament) being a great temptation to individual adventurers, interlopers, who had often given them much trouble, became again very numerous, and attempts were made to get the trade laid open, or to have it vested in a regulated company similar to those by which the trade with Turkey and with some other countries was then carried on. The company, however, in 1683 found means to obtain a new charter, by which all their former privileges were confirmed, and they were empowered to seize the ships and merchandize of all interlopers, to raise and maintain military forces, to exercise martial law,

and to establish a court of judicature for determining all mercantile causes, within their limits. In 1686 they obtained another charter granting them still greater powers and privileges.

Soon after the revolution much popular clamour was raised against the East India company; and in 1691 the house of commons addressed the king to dissolve the company and incorporate a new one; an opportunity for which soon occurred, as in 1693, the charter of the company became void, from their not paying the duty which had been imposed on their stock within the time limited by the act; but a new charter was granted them, on condition of submitting to such regulations as should be ordained before the 29th of September 1694 and which were contained in two charters soon afterwards executed.

In 1698 the complaints of the weavers of London against the importation of India wrought silks, and the company having been prevented by losses from making any dividends for several years, brought it into much disrepute, and the house of commons thought it necessary to take the state of their affairs into consideration. The company thought it prudent to offer to advance 700,000 *l.* for the public service at 4 per cent. interest, provided the exclusive trade was legally settled on them; but a number of merchants, countenanced by the chancellor of the exchequer, proposed to advance 2,000,000 *l.* at 8 per cent. interest, for similar privileges. The latter proposal was approved, and an act passed by which a new company was established; many difficulties however appeared, with respect to their engaging in the trade, till the expiration of the three years notice for determining the old company. During this unsettled state of the East India trade, the old company's stock had in about nine or ten years fluctuated from 300 per cent. to only 37 per cent.

The great contentions which ensued between the old and new companies, soon rendered it obvious that little benefit would be derived from the trade, unless a coalition between the two rival corporations was effected. This was accomplished in 1702, by an agreement that the old company should purchase an equal proportion of stock in the new company, and that the separate traders, who had subscribed to the new company, but not to their joint-stock, should be included in the union. The old company was to keep their stock in the new company, in their corporate capacity for seven years, then to transfer it to their respective members, and resign their charter to the crown, from which time the new company comprehending the proprietors of both, assumed their present title of "The united Company of Merchants of England trading to the East Indies." In 1708 the term of their exclusive trade to India, which was determinable upon three years notice after 1711, and repayment of the sum they had advanced, was prolonged to three years notice after Lady-day 1726; for which they advanced to government 1,200,000 without any additional interest. In 1712 they obtained an act for continuing the trade and corporation capacity of the company, although the sums they had advanced to government should be repaid; which repayment or redemption of their annual fund, was not to be made till the expiration of three years notice after Lady-day 1733.

The act of parliament being liable to a different construction from what was probably intended, and the term granted being near its expiration, a very powerful opposition to its renewal, was raised in 1730, and specious proposals were made to parliament for redeeming the fund of the company, and transferring the trade to a regulated

company, with similar privileges. After a very full discussion of the subject, a new agreement was entered into with the company, who agreed to pay 200,000 *l.* towards the service of the current year, and to have the interest payable to them by government reduced from 5 to 4 per cent.; in consideration of which all their exclusive privileges were continued till the expiration of three years notice, to be given after Lady-day 1766, when upon re-payment of their entire capital of 3,200,000 *l.* their exclusive privileges were to cease, but the company to continue a corporation for ever, to enjoy the East India trade in common with all other subjects. In consequence of this reduction of the interest received from government, they thought proper to reduce the dividend payable to their proprietors from 8 to 7 per cent. and soon after to 6 per cent.

In 1743 the company proposed to advance 1,000,000 *l.* for the service of the year 1744, at 3 per cent. interest, on having the term of their exclusive trade enlarged for fourteen years, and being permitted to borrow a million on bonds. This proposal being accepted, the debt from the public to the company became 4,200,000 *l.*, and the exclusive trade was now extended to three years notice, to be given by parliament after Lady-day 1780, with the former provision, that, after such determination, the company should continue to have a common right with other subjects in the trade to India.

The company not subscribing to the reduction of interest proposed in 1749, the speaker of the house of commons was ordered to give them notice that the sum due from government would be paid off, unless they subscribed before May 30, 1750: with this it was deemed prudent to comply, but a condition was made, that in order to enable the company to reduce their bond debt, they should be empowered to raise money by the sale of 3 per cent. annuities, to the amount of the debt of government to the company. The annuities thus sold were known by the title of 3 per cent. India annuities, and were for many years payable at the India house, but are now consolidated with the 3 per cent. reduced bank annuities.

Hitherto the company had not aspired beyond their original character of merchants, and merely possessed factories at the principal ports to which they traded; these factories were, for the safety of their merchandize and the protection of their servants, converted into forts, which rendered it necessary to maintain a military establishment. Thus possessed of the means of offence as well as defence, they made considerable exertions to oppose the progress of the French in those parts; and as the two companies each endeavoured to procure the assistance of the neighbouring native princes, the field of interest and ambition became much enlarged. In 1751, the company sent a considerable military force into the province of Arcot to support the nabob against his rival, who was powerfully assisted by the French; in which contest they were engaged with little intermission for several years. In Bengal, the company had carried on their commercial intercourse without any connexion with territorial authority, till the death of the subah Ali-Verdi-Khan, in 1756. This prince had viewed their increasing opulence and power with great jealousy, and a short time before his death gave a remarkable charge to his successor, in which he cautioned him to keep in view the power of the European nations in his country, and to free himself from their influence as soon as possible. "The power of the English is great; reduce them first; the others will then give you little trouble. Suffer them not to have forts or soldiers; if you do, the country is not yours." In attempting to put

this advice into execution, Sou-Rajah-Dowla was completely defeated by the company's forces, and the new subah of their appointment, besides paying to the company a very large sum for their losses and expences, ceded to them a considerable territory in the vicinity of Calcutta. On the coast of Coromandel, hostilities were carried on against the French settlements with unequal success, but ultimately to the advantage of the English, upon which the subah of the Deccan concluded a treaty with the company, and ceded to them the entire circle of Masulipatam. In 1760, the company's forces completely defeated those of France, and in the following year captured Pondicherry, the chief of the French settlements in India; since which events the power of France in India has been very insignificant.

Such was the commencement of the company's acquisitions of territory, which they have seized every subsequent opportunity of extending, till the sovereigns of India, whose protection they formerly courted, have sunk into the situation of their dependents, and hold their precarious dignities at the will and pleasure of a society of foreign traders.

The annual sales of the imports of the company for sixteen years preceding 1757, amounted on an average to about 2,055,000*l.*; and for the same period, the exported goods and stores amounted annually, at their prime cost, to 238,000*l.*; the bullion exported to 690,000*l.* per annum, and they paid in discharge of bills of exchange 190,000*l.* per annum.

Early in 1764, on the receipt of some unpleasant news from Bengal, India stock fell 14 per cent. The general administration of the company's affairs, both at home and abroad, became soon after the subject of much discussion; and on 29th August 1766, the court of directors received a notice from the secretaries of state, that an investigation would

take place in the next session of parliament. The administration laid claim to the territories which the company had acquired in India, with the revenue arising from them, as of right belonging to the crown; but as the company were very unwilling to have this new source of wealth taken out of their hands, a temporary agreement was made for two years, by which the company, in compensation for this claim, agreed to pay to government 400,000*l.* a year. In 1769, the agreement was renewed for five years, and the territorial acquisitions and revenues in India secured to the company for that term, with a stipulation that the company should be allowed to increase their dividend to 12½ per cent., but not to increase it more than one per cent. in one year.

They now became involved in a war with the famous Hyder Ally, in consequence of which, and of the misconduct of their servants in India, the concerns of the company, from the most flourishing situation, were brought into the greatest embarrassments. Select and secret committees of the house of commons were appointed to investigate the state of their affairs; and in 1773, it appeared, not only that they were unable to make the stipulated annual payment to government, but that it was necessary to assist them with a loan of 1,400,000. Till this sum should be repaid, the dividend to their proprietors was not to exceed 6 per cent., and afterward not to exceed 7 per cent. till their bond debt was reduced to 1,500,000*l.* From these circumstances, the price of the company's stock fell considerably from the latter part of 1772 till February 1774, when their affairs began to wear a brighter aspect. In 1776, the loan from government had been repaid, and their situation being otherwise improved, the dividend on their stock was raised to 8 per cent.

Statement of the Company's Revenues, at their different Settlements in India, in the Year ending April 1777.

To expences in Bengal, civil, military, and fortifications	- £ 1,350,000	By nett revenues in Bengal	- - £ 2,500,000
To ditto at Fort St. George	560,000	Benares tribute	- - 290,000
To ditto at Bombay	360,000	Oude subsidy	- - 370,000
		By revenues of Fort St. George and the Circars	560,000
	2,270,000	Tanjore subsidy	- - 160,000
Nett balance of the year's revenues	1,770,000	By revenues of Bombay, &c.	160,000
	£ 4,040,000		£ 4,040,000

On an average of ten years, ending with 1777, the company's exports in goods were about 490,000*l.*; in bullion, 110,000*l.*; and the sum paid in discharge of bills of exchange, 458,000*l.* per annum. By the aid afforded from the revenues, their investments were increased, so as to produce about 3,330,000*l.* per annum.

In 1779, an act was passed for continuing the territories and revenues in India in the possession of the company for one year, which in 1780 was continued for another year. In June 1781, it was agreed to offer to pay into the exchequer 400,000*l.*, in full discharge of all claims of the public upon the company up to the 1st of March; and as, in the preceding year, they had received notice that the 4,200,000*l.* due to them from government would be paid off on the 10th of April, 1783, it became necessary to enter into a new agreement, the conditions of which were, that the company should continue to enjoy their exclusive privileges to the 1st of March, 1794, then to cease and determine, upon the former conditions of three years previous

notice, and the repayment of all sums due to them. The surplus of their nett profits, after paying their dividends, were appropriated, three fourths for the service of government, and one fourth to be retained by the company; and they were restricted not to increase the dividend of 8 per cent. more than 1 per cent. in any year. This restriction was, however, soon found unnecessary; for the nett profits of the company for the year ending 1st of March, 1782, did not amount to so much as a dividend of 8 per cent. on their stock by 22,023*l.*; in consequence of which, it became necessary for government to allow a farther time for the payment of 396,466*l.* 2*s.* 6*d.*, which was due from the company for customs, besides a part of the sum which they had agreed to pay in 1781; and they were at the same time empowered, notwithstanding the above deficiency, to continue their dividends at 8 per cent. In the following year, the war in India, and other circumstances, increased the embarrassment of the company's affairs; and, by a statement of their accounts to the 1st of March, 1783, it appeared that

the nett profits of that year did not amount to a dividend of 8 per cent. by 255,813*l.*, which dividend they were nevertheless authorized by parliament to continue; and, to enable them so to do, government issued exchequer bills to the amount of 300,000*l.*, which the bank undertook to lend money upon to the company.

The long and expensive war in which the company had been engaged in India, terminated in March 1784, by the ratification of peace with the Mysorean government; but the consequence of this war, in addition to the war in Europe, was the general derangement of the company's affairs both at home and abroad. In December 1783, February and May 1784, the directors laid before parliament such accounts as they then possessed, respecting the general state of their finances. But the impossibility of drawing any satisfactory information from statements made up in such a situation of their affairs, with the apprehensions which the measures then in agitation, relative to the future government of India, had excited in the public mind, reduced the credit of the company to the lowest ebb. Their stock sold as low as 118½; their bonds at home, bearing 5 per cent. interest, were negotiated from 2½ to 4 per cent. discount; their bonds and certificates, at Bengal and Madras, bore from 18 to 40 per cent. discount; at Bombay 50 per cent.; and orders on the treasury there sold at 65, and upwards, per cent. discount.

It now became a general conviction, that the company was incompetent to the political government of the extensive territories which they had acquired. A Board of Controul was therefore established, composed of a certain number of commissioners to be appointed by the king, and removeable at his pleasure. This board was authorized to check, superintend, and controul, the civil and military government and revenues of the company. The dispatches transmitted by the directors to the different presidencies were to be previously subjected to the inspection of the Board. The appointment of governor-general, president, or counsellor in the different presidencies, was made subject to the approbation and recall of his majesty; and such other regulations adopted, as in a great measure deprived the company of that political and civil authority which they had suffered to be so grossly abused.

In 1786 some further regulations were made respecting the government of India; and, as the company's trade was increasing, particularly in the article of tea, their import of which had been greatly augmented by the arrangement of the commutation act, they were said to require a greater capital, and were authorized to create 800,000*l.* new stock, on which they raised 1,240,000*l.* at the rate of 155 per cent. In 1789 they obtained another act, enabling them to add 1,000,000*l.* to their capital, which thus became 5,000,000*l.*

In the beginning of 1793, the term of the company's exclusive privileges being nearly expired, the subject of laying open the trade to India was again discussed, and though it was not thought proper to risk the loss and confusion which must unavoidably attend any attempt to take such an immense concern out of the hands in which it has so long continued, a stipulation was made in the agreement for the renewal of the charter, that such regulations should be adopted as to admit of a free exportation by private persons on their own account, of any goods of the growth, produce, or manufacture of Great Britain or Ireland; and of a free importation of such sorts of the raw materials of the East Indies as are used in the manufactures of Great Britain or Ireland; that the company should be obliged to provide shipping for the carriage of the private trade, at as low a

freight as it could be furnished by private merchants; and that they should license a proper number of agents to reside at the company's settlements, under their protection, for the management of the private trade. On these conditions the company's term in the exclusive trade was enlarged for 20 years, or to the 1st of March, 1814, with the former proviso, that if, after the expiration of that term, their right to the sole trade shall cease, in consequence of three years previous notice being given by parliament, and the repayment of such sums as may be then due from the public, they shall continue a corporation, with power to carry on a free trade in common with other persons.

On this occasion, the total income of the company, arising both from their territorial revenues and their commercial concerns, was stated as follows:

The nett annual income in rents and profits of trade, taken in the most unfavourable light to the company, and supposed to be considerably under the mark, was rated at - - -	£2,329,164
Subject to the following payments, viz.	
Interest of 3,200,000 <i>l.</i> on bond, at 4 per cent. - - -	£128,000
Ditto of 6,669,082 <i>l.</i> debt in India, at various rates of interest, on a medium about 8½ per cent. - -	561,923
Dividend of 8 per cent. on their capital of 5,000,000 <i>l.</i> - - -	400,000
	<hr/> 1,089,923

Leaving a nett annual surplus of - - - £1,239,241

Of this surplus it was proposed to appropriate 500,000*l.* per ann. to the reduction of the debt in India, to pay 500,000*l.* per annum to government in half yearly payments, and to pay an increased dividend of 10 per cent. to their proprietors on 6,000,000*l.* to which sum their capital was now raised.

This annual surplus, if it really existed at the time to which the above account refers, was of very short duration. In 1795 the company found themselves unable to continue the proposed contribution to government; and the intrigues of Tippoo Saib with the French, and with some of the native powers, which obliged the company to keep up a large military establishment, and soon after to engage in another expensive war, not only reduced the surplus of their revenues, but occasioned a considerable increase of debt in India, which has since been further augmented in consequence of hostilities with Dowlut Rao Scindia and Jeswunt Rao Holkar.

In order to furnish some idea of the extent of the company's commercial and financial concerns, the following accounts are subjoined.

The amount of all goods sold at the East India Company's sales, from the 1st of March 1805 to the 1st of March 1806.

Company's goods; viz.	
Teas - - - - -	£3,620,904
Bengal piece goods - - - - -	621,862
Coast and Surat piece goods - - - - -	614,317
Raw and organzine silk - - - - -	274,459
Nankeens - - - - -	65,240
Pepper - - - - -	121,844
Saltpetre - - - - -	217,769
Spices - - - - -	114,545
Drugs, sugar, coffee, &c. - - - - -	348,350

5,999,290

Private Trade goods, viz.	
Teas - - - - -	£239,215
Piece goods - - - - -	772,517
Raw silk - - - - -	442,228
Nankeens - - - - -	21,489
Pepper - - - - -	10,633
Saltpetre - - - - -	144
Drugs, sugar, indigo, &c. - - - - -	1,693,926
	<u>2,782,152</u>
Total - - - - -	£8,781,443

An Estimate of the revenues and charges in India, for the year 1806-7.

Revenues.	
Bengal - - - - -	£9,148,711
Madras - - - - -	5,021,325
Bombay - - - - -	677,203
Total - - - - -	<u>£14,847,239</u>
Charges.	
Bengal, civil and military expenses - - -	£6,944,607
Madras - - - do. - - - - -	5,379,218
Bombay - - - do. - - - - -	1,826,516
Commercial charges not added to invoices - -	192,769
Interest of debts - - - - -	2,275,300
Supplies to Prince of Wales' island, &c. - -	185,600
Total - - - - -	<u>£16,804,010</u>
Deduct estimated revenues - - - - -	14,847,239
Deficiency - - - - -	<u>£1,956,771</u>

Account of the actual receipts and payments of the East India Company, in Great Britain, for one year, ending the 1st of March 1807.

Receipts.	
Cash in the Treasury 1st March 1806 - -	£669,794 6 2
For company's goods sold - - - - -	5,294,384 13 8
Of the board of ordnance for saltpetre - -	160,000 0 0
Private trade goods sold - - - - -	2,114,269 8 10
Charges and profit on private trade - -	163,462 19 2
Customs on do. - - - - -	73,380 19 5
Freight on do. - - - - -	119,784 18 10
Interest on red. 3 per cent. annuities - -	36,266 15 10
Of government, on account of a sum due to the company - - - - -	1,000,000 0 0
Alms-houses at Poplar - - - - -	2,416 18 2
Persons returned from India - - - - -	17,516 0 0
Bonds issued - - - - -	517,000 0 0
Duty on tea received - - - - -	3,120,290 12 3
Total - - - - -	<u>£13,288,527 12 4</u>

Payments.	
Customs - - - - -	161,736 14 0
Freight and demorage - - - - -	1,689,040 9 4
Goods and stores exported - - - - -	2,270,793 7 8
India debt - - - - -	50,223 19 5
Bills of exchange from India - - - - -	342,885 1 8
Ditto from China - - - - -	641,994 16 8
Bullion exported - - - - -	514,432 16 8
Charges of merchandize, including supra cargoes, commission, interest on loans, &c. - - - - -	623,652 14 11

	£	s.	d.
Dividends on stock and interest on bonds - -	770,429	19	1
Bonds paid off and paid in on sales - -	216,600	0	0
Proprietors of private trade - - - - -	2,169,021	15	0
Pay to marine and military officers on furlough, and retired from service - -	141,319	15	0
Duty on tea paid - - - - -	3,184,417	6	7
Cash in the treasury 1st March 1807 - -	511,978	16	4
	<u>£13,288,527</u>	<u>12</u>	<u>4</u>

The vast concerns of this company are under the management of twenty-four directors, who are formed into different committees; each committee having the superintendence of a particular department of the company's business. At the general courts of proprietors, persons possessing 1000*l.* stock have one vote; 3000*l.* two votes; 6000*l.* three votes; and 10,000*l.* four votes. The number of proprietors entitled to vote, on the 8th of April 1800, was 2163, and the number of votes 2832.

COMPANY, *Hamburg*, is the oldest trading establishment in the kingdom; though not always known by that name, nor restrained to those narrow bounds under which it was afterwards confined. It was first called, the Company of Merchants trading to Calais, Holland, Zealand, Brabant, and Flanders: then it acquired the general title of Merchant-adventurers of England; as being composed of all the English merchants who traded to the Low Countries, the Baltic, and the German ocean. Lastly, it was called the Company of Merchant-adventurers of England trading to Hamburg.

This company was not a society of dealers, each furnishing a part of the sum to constitute the capital stock of the company; but a mere association, or body of merchants, who had nothing in common, but the grant and privilege of trading to Hamburg, and some other cities of Germany; each managing his own commerce, and trading on his own foundation; only observing a certain discipline, and some regulations, which none but the company could establish or change.

This company was first incorporated by Ed. 1. in 1296; and established again, by charter, in 1406, under the reign of Henry IV. It was afterwards confirmed and augmented with divers privileges, by many of his successors; among the rest, by Henry V. in 1413; Henry VI. in 1422; Henry VII. in 1493, 1505, and 1506; Henry VIII. in 1509, 1517, and 1536; Edward VI. in 1547; queen Mary, in 1553; Elizabeth, in 1564, and 1586; James I. in 1605; and Charles II. in 1661. But of all these charters, none but those of Henry IV. Henry VII. Elizabeth, James, and Charles, were of any importance, or gave the company any thing new; the rest being only confirmations. Before the charter of Henry IV. all the English merchants, who trafficked out of the realm, were left to their own discretion, and managed their affairs with foreigners as might be most for their respective interests; without any regard to the general commerce of the nation.

Henry observing this disorder, endeavoured to remedy it, by uniting all the merchants in his dominions into one body; wherein, without losing the liberty of trading each for himself, they might be governed by a company; and be subject to regulations, which should secure the general interest of the national commerce, without prejudice to the interest of particulars. With this view, he granted all the merchants, of his states, particularly those of Calais, then in his hands, a power of associating themselves into a body politic, with

directors and governors, both in England and abroad; to hold assemblies both for the direction of business and the deciding of controversies among merchants; make laws, punish delinquents; and impose moderate duties and taxes on merchandizes and merchants to be employed in the service of the corporation.

These few articles of the charter of Henry IV. were afterwards much augmented by Henry VII. who first gave them the title of Merchant-adventurers to Calais, Holland, &c. gave them a power of proclaiming and continuing free fairs at Calais; and ordered, that to be reputed a member of the society, each person should pay twenty marks sterling; and that the several members should attend the general meetings, or courts, appointed by the directors, whether at London, Calais; or elsewhere.

The inexecution of this last article and contempt of some of the rest, occasioning great inconveniences to the company's affairs, another charter was procured, whereby the pain of imprisonment was menaced, for those who should absent themselves from the meetings without lawful cause, or should disobey the laws. A petition being made to queen Elizabeth, in 1564, for an explanation of certain articles in the charter of Henry VII. and a confirmation of the rest granted by other kings; that princess, by a charter of the same year, declares, that to end all disputes, they should be incorporated anew under the title of the "Company of Merchant-adventurers of England;" that all who are members of the former company should, if they desire it, be admitted members of this; that they should have a common seal; that they should admit into their society what other persons, and on what terms, they please; and expel them again on misbehaviour; that the city of Hamburg, and neighbouring cities, should be reputed within their grant, together with those of the Low Countries, &c. in that of the former company; that no member should marry out of the kingdom, nor purchase lands, &c. in any city beyond sea; and that those who do, shall be *ipso facto* excluded for ever.

Twenty-two years after this first charter, queen Elizabeth granted them a second; confirming the former, and further granting them a privilege of exclusion, with a power of erecting in each city within their grant, a standing council.

The woollen manufacture being the principal object of their application, they met with great opposition; first, from the Hanse, who forced them frequently to change their mart, or staple; and afterwards under king James I. who having erected a corporation in 1616, in favour of some private persons, who offered to set up a manufacture for dyeing and pressing cloths, &c. under pretence thereof the company of merchant-adventurers were prohibited dealing therein. But that project not succeeding, and the charter being revoked two years afterwards, the merchant-adventurers, whose company had been dissolved two years before, were restored in 1617, to their ancient privileges, and a new charter was given them, confirming their exclusive rights; and allowing them to have officers in the several custom-houses, to have an eye that they were not prejudiced in their woollens, under pretence of the like merchandizes, which others were allowed to send to other parts. This charter of king James, is the last of those confirmed by Charles II. in the grand charter of 1661.

The revolutions which had happened in the Low Countries towards the end of the sixteenth century, and which laid the foundation of the republic of Holland, having hindered the company from continuing their commerce with their ancient freedom; it was obliged to turn it almost wholly to the side of Hamburg, and the cities on the

German ocean; from which change some people took occasion to change its name to that of the Hamburg company, though the ancient title of Merchant-adventurers is still retained in all their writings.

This society was greatly reduced, when its trade was laid open by William III. and the company is now extinct.

COMPANY of Merchants of the Staple was incorporated by Edward III. Their factory was at Middleburgh, in Zealand; but the staple being removed, in 1389, to Calais, it was soon after, *viz.* in 1390, removed from thence to England.

COMPANY, Russia. This was first projected towards the end of the reign of king Edward VI. executed in the first and second years of Philip and Mary; but had not its perfection, till its charter was confirmed by act of parliament, under queen Elizabeth, in 1566. It had its rise from certain adventurers, who were sent in three vessels on the discovery of new countries; and to find out a north-east passage to China; these, falling into the White sea, and making up to the port of Archangel, were exceedingly well received by the Muscovites; and at their return, solicited letters patent to secure to themselves the commerce of Russia, for which they had formed an association.

The charter was promised them by Edward VI. but he dying, was first dispatched by queen Mary, in 1555. By this charter, the association was declared a body politic, under the name of the "Company of Merchant-adventurers of England, for the discovery of lands, territories, islands, &c. unknown or unfrequented." Their privileges were, to have a governor, four consuls, and twenty-four assistants, for their commerce; for their policy, to make laws, inflict penalties, send out ships to make discoveries, take possession of them in the king's name, set up the banner royal of England, plant them; and lastly, the exclusive privilege of trading to Archangel, and other ports of Muscovy, not yet frequented by the English.

This charter, not being sufficiently guarded, was confirmed by parliament in the eighth year of queen Elizabeth, wherein it was enacted, that in regard the former name was too long, they should now be called "Company of English Merchants for discovering new trades;" under which name, they should be capable of acquiring and holding all kinds of lands, manors, rents, &c. not exceeding a hundred marks per ann. and not held of her majesty; that no part of the continent, island, harbour, &c. not known nor frequented before the first enterprize of the merchants of their company, situate to the north, or north-west, or north-east of London; nor any part of the continents, islands, &c. under the obedience of the emperor of Russia, or in the countries of Armenia, Media, Hyrcania, Persia, or the Caspian sea, should be visited by any subjects of England, to exercise any commerce without the consent of the said company, on pain of confiscation. The said company shall use no ships in her new commerce, but those of the nation; nor transport any cloths, serges, or other woollen stuffs, till they have been dyed and pressed. That in case the company discontinue of itself to unload commodities in the road of the abbey of St. Nicolas, in Russia, or some other port, on the north coasts of Russia, for the space of three years, the other subjects of England shall be allowed to traffic to Narva, while the said company discontinues its commerce into Russia, only using English vessels.

This company subsisted with reputation almost a whole century, till the time of the civil wars. It is said, the czar then reigning, hearing of the murder of king Charles I. ordered all the English in his states to be expelled; which the Dutch taking the advantage of, settled in their room

After the restoration, the remains of the company re-established part of their commerce at Archangel, but never with the same success as before: the Russians being now well accustomed to the Dutch merchants, and merchandize.

This company subsists still, nearly on the foot of that of Hamburg, and the northern and Turkey companies; i. e. each member thereof trafficks for himself, and on his own foundation; only paying an acknowledgement as fine for admission, which was reduced by 10 and 11 W. III. c. 6, to five pounds; besides some other dues imposed, from time to time, for the occasions of the company, and the commerce in general. It is under the direction of a governor, four consuls, and assistants.

COMPANY, *Eastland*, is established on similar ground with that of Hamburg; from whence it appears to have been dismembered.

Its charter is dated in the year 1579. By the first article the company is erected into a body politic, under the title of the "Company of Merchants of the East;" to consist of Englishmen, all real merchants, who have exercised the business thereof, and trafficked through the Sound, before the year 1568, into Norway, Sweden, Poland, Livonia, Prussia, Pomerania, &c. as also Revel, Koningsberg, Dantzick, Copenhagen, &c. excepting Narva, Muscovy, and its dependencies. Most of the following articles grant them the usual prerogatives, of such companies; as a seal, governor, courts, laws, &c.

The privileges peculiar to this company are, that none shall be admitted a member who is already a member of any other company; nor any retail dealer at all. That no merchant qualified, be admitted without paying 6*l.* 13*s.* 6*d.* By 29 C. II. c. 7. the fee of admission into this company was reduced to 2*l.* That a member of another company, desiring to renounce the privileges thereof, and to be received into that of the East, shall be admitted *gratis*; provided he procures the same favour for a merchant of the East, willing to fill his place. That the merchant adventurers who never dealt in the East, in the places expressed in the charters, may be received as members of the company on paying forty marks; that, notwithstanding this union of the adventurers of England with the company of the East, each shall retain its rights and privileges. That they shall export no cloths but what are dyed and pressed, except a hundred pieces per annum, which are allowed them *gratis*.

This charter was confirmed by Charles I. in 1629, with this addition; that no person of what quality soever, living in London, should be admitted a member, unless he were free of the city.

This company was complained of as a monopoly, and first curtailed by legal authority in 1672; and since the declaration of rights in 1689, exists only in name; but they still continue to elect their annual officers, who are a governor, deputy, and twenty-four assistants.

COMPANY, *Turkey, or Levant*. This once flourishing body had its rise under queen Elizabeth, who, in 1581, incorporated a small number of merchants, with the privilege of an exclusive trade to Turkey for seven years. James I. in 1605, confirmed their charter, with the addition of some new privileges. During the civil wars some innovations were made in the government of the company; many persons having been admitted members, not qualified according to the charter, or who did not conform to the regulations prescribed, in consequence of which Charles II., upon his restoration, endeavoured to place it upon its ancient basis, for which purpose he gave them a new charter, containing a confirmation of the old one with some additional

articles. By this charter the company was declared to be a body politic, capable of making laws, &c. under the title of "The Company of Merchants of England trading to the Seas of the Levant." The number of members was not limited, but no person residing within twenty miles of London, excepting noblemen and gentlemen of quality, was to be admitted into the company, unless first made free of the city of London: those under 26 years of age were to pay 25*l.* for their admission, and those above that age 50*l.* These fines were reduced by an act passed in 1753. (26 Geo. II. c. 18.) by which it is directed that every subject of Great Britain desiring admission into the Turkey company, shall be admitted within thirty days after such request, and shall enjoy all the liberties and privileges of the company, on paying for such admission the sum of 20*l.*

All persons free of the company may, separately or jointly, export any goods or merchandize (not prohibited) from any place in Great Britain, to any place within the limits of the company's charter, in British or plantation built ships, navigated according to law, at any time, and to any persons whomsoever, being free of the company, or to the sons or apprentices of freemen, so long as they shall remain under, and submit to, the direction of the British ambassador and consuls for the time being; and may also import, in like manner, any commodities purchased within the company's limits, on payment of the government duties, and such impositions as shall be assessed upon all merchandize so exported or imported, or upon ships laden therewith, for defraying the necessary expences of the company.

The company is under the management of a governor, a deputy governor, and fifteen directors; they have also a deputy governor in every city and port where there are any members of the company. They present the ambassador which the king is to keep at the Porte, and elect two consuls for Smyrna and Constantinople; allowing a fixed salary or pension to the ambassador and consuls, and even to their chief officers, as secretary, chaplain, interpreters, and janizaries, that they may not have any pretence for raising any sum whatever on the merchants or merchandize. For defraying these charges the company have power to levy duties on the merchandize imported or exported by their members; but of late years they have frequently found it necessary to apply to parliament for pecuniary assistance.

The commerce of this company was formerly very considerable, having been estimated nearly equal to that of the East India company in extent, and much more advantageous to Great Britain; but the convenient situation of the French ports in the Mediterranean for the Levant trade, gives that country such a decided advantage, that the commerce of Great Britain with Turkey has long been on the decline. In 1797, in order to avoid the hazard to which British vessels in the Levant trade were exposed in consequence of the war, an act was passed giving permission to the members of the Turkey company to import the goods usually brought from Turkey, Egypt, or other parts of the Turkish dominions in the Levant seas, from any port whatsoever, either in British vessels or vessels belonging to any friendly nation, on paying, if in British vessels, the same duties which would have been payable if the goods had been imported directly from the place of their growth, and, if in foreign vessels, the duties to which they were before liable; but no entry of such goods was to be made at the custom house till the importer produced a certificate of his being a member of the Turkey company, and that he had paid the company's duties, and in all respects conformed to the company's regulations.

COMPANY, South Sea, originated in a project for relieving the government from the embarrassment of a large amount of unfunded debts, and considerable deficiencies in the funds appropriated for the payment of others; the proprietors of these debts being incorporated for the ostensible purpose of establishing a trade to the south seas and the N.W. coast of America. The capital of the company was 9,177,967*l.* 15*s.* 4*d.*; but this being subscribed wholly in government securities, they issued bonds in 1712, for raising 200,000*l.* in cash in order to fit out their first mercantile adventure. In the following year, they obtained the *Asiento* contract, by which they agreed to import into the Spanish West Indies 144,000 negroes, within the term of 30 years, at the rate of 4800 in each year, and were allowed to send a ship of 500 tons yearly to trade with the Spanish settlements, on condition that the king of Spain should have a fourth part of the gain by such ship, and receive five per cent. on the nett gain of the other three parts. See *ASIENTO*.

The first voyage of their annual ship was in 1717, and the company were again empowered to borrow money under their common seal, for carrying on their trade, or to enable them to fulfil an engagement with government to advance two millions towards carrying into execution a proposed reduction of interest on the public debts. On the war breaking out in the following year, a stop was put to their trade with the Spanish West Indies, by the seizure of their effects, by which they sustained a very considerable loss.

Soon after this interruption of their commercial concerns, they engaged in a scheme for converting some of the government terminable annuities into redeemable debts. They had, in 1715, for the accommodation of government, agreed to increase their capital to 10,000,000*l.*, which, by the annuities now purchased, and an advance to government, became 11,746,844*l.* 8*s.* 10*d.*; and although the scheme did not completely succeed, it prepared the way for the much more extensive project of taking in all the public debts, and thus reducing all the public funds which then existed into one.

The mere rumour of this mercantile project raised the price of the company's stock to 126 per cent.; and, in the beginning of 1720, while the bill for carrying it into execution was depending in parliament, their stock got up from 137 to 319 per cent. As the transaction consisted merely in taking the public debts at a fixed price, and giving the proprietors, in exchange, a certain quantity of the company's capital stock, at prices agreed upon between the company and the subscribers, it is evident that the great gain which the company expected to make, could arise only from the current price of their stock being considerably above its real value. By a variety of artifices, and a general stock-jobbing infatuation, it was carried up to the enormous price of 1000 per cent.: the rapidity of its fall, however, exceeded that by which it rose, as it was in a few weeks down to 130 per cent.; involving in ruin persons of all descriptions who were engaged in the wild speculations of the time. (See *BUBBLE*.) Had the transaction completely succeeded, the capital of the company would have amounted to 43,411,399*l.* 6*s.* 11*d.*, but from some of the debts remaining unsubscribed, it became 37,802,483*l.* 1*s.* 0*d.* of which four millions were purchased in 1722 by the bank, and in the following year the remainder was divided into two equal parts, one of which was to be called the trading capital of the company, and the other to be distinguished by the title of "The joint stock of South Sea annuities," since called old South Sea annuities.

In 1724, the company undertook the Greenland whale

fishery, which turned out very unprofitable: after eight voyages, they sold their ships, stores, and utensils, and found that their whole loss upon this business, capital and interest included, amounted to 237,142*l.* 6*s.* 2*d.*

In 1753, three fourths of their trading capital, which had been reduced by sums paid off in 1727, 1729, and 1732, to 14,631,103*l.* 8*s.* 1*d.*, was converted into an annuity stock called "New South Sea Annuities," only one fourth remaining as their trading stock; and, in the following year, they petitioned the king to be allowed to dispose of the trade and tonnage of their annual ship under the *Asiento* contract, on account of the little profit they made by it, and to accept of such equivalent as they could obtain from the king of Spain, who at length, to put an end to the many disputes which had arisen from this contract, agreed, in 1750, to pay 100,000*l.* to the company, as a compensation for all claims under the *Asiento* contract, and from that period they have not carried on any trade whatever. The whole business of the company, therefore, now consists in the management of the following public funds.

Their capital stock	-	-	£ 3,662,784	8	6
Old South Sea annuities	-	-	11,907,470	2	7
New South Sea annuities	-	-	8,494,830	2	10
Three per cents., 1751	-	-	1,919,600	0	0

The interest received from government on all these funds, is 3 per cent., but the dividend paid to the proprietors of the company's stock, is 3½ per cent.; on the old and new annuities, 3 per cent.

The company is under the management of three governors, and 21 directors; the qualification required for governor, is the possession of 5000*l.* in the company's stock; for sub-governor, 4000*l.*; for deputy-governor, 3000*l.*; and for a director, 2000*l.* Five hundred pounds stock, gives a right to one vote at the general courts; 2000*l.* to two votes; 3000*l.* to three votes; and 5000*l.* to four votes.

COMPANY, Scotch Darien. This was established with good prospect at Edinburgh, in 1695, for the commerce of South America. In 1698, they sent an armament and a colony, which they endeavoured to establish in the isthmus of Darien, which parts North and South America; but the English ministry not thinking proper to avow and support the first successes of the company, which had alarmed Spain, ever jealous of this part of her territories, the Scotch colony was dispersed by the Spaniards in 1699, and thus vanished the best project that ever was formed for disputing with that nation the possession of those countries, from which she pretends to exclude all other nations.

COMPANY, Hudson's Bay, was incorporated by charter, dated the 2d of May, 1670, under the title of "The Governor and Company of Adventurers of England, trading into Hudson's Bay," with the exclusive privilege of trading to all parts within the entrance of the freight commonly called Hudson's freights. The charter, however, not being confirmed by act of parliament, the company possess no exclusive rights whatever, any British subject being at liberty to sail into Hudson's Bay, to fish or traffick with the Indians as freely as the company; all the advantage the company have over other adventurers thither is merely the benefit of their own forts, such as they are, by which their agents can reside in so inhospitable a country during the winter, preparatory to their trading with the Indians against the arrival of their ships in the summer. According to the evidence given before a committee of the house of commons in 1749, the company then possessed four small factories, erected at the mouths of the principal rivers, in which they employed about 130 per-

sons, and two small houses with only eight men in each; these buildings are necessarily strong, as well to guard against the climate as against other dangers, and are furnished with artillery to command respect from the Indians; they have therefore been generally called forts, although no military force is kept for defending them: their utility in resisting any serious attack, was obvious in 1782, when the French, who at former periods had done the company much injury, destroyed their settlements, forts, merchandize, &c. to the estimated amount of near 500,000 *l*.

The capital of the company, it is said, does not exceed 110,000 *l*. which is divided among a very small number of proprietors. The commerce carried on by them is not of great extent, as it seldom employs above four or five ships of about 300 tons each. The articles exported by them are coarse duffle cloth or blanketing, guns, pistols, sword blades, hatchets, powder and shot, spirits, tobacco, brass kettles, buttons, fish hooks, looking glasses, &c.; the imports consist of large quantities of beaver skins, and peltry of all kinds, bed feathers, quills, castoreum, whalebuns, oil, and a few smaller articles.

The company is under the management of a governor, deputy governor, and a committee of seven members.

COMPANY, *Sierra Leone*, was set on foot in the year 1791, with the philanthropic view of introducing civilization into Africa. The principal means proposed for effecting this end was the establishment of a secure factory for carrying on an extensive commercial intercourse with the interior; but before the arrangements for this purpose were completed, the reception into the settlement of near 1200 blacks, who had taken part with Great Britain in the American war, and had petitioned the government to be removed from Nova Scotia on account of the coldness of the climate, involved the company in considerable difficulties, and gave a new character to the undertaking. Their expences, from various causes, became much greater than could have been foreseen, amounting in the first two years and a half to 111,500 *l*. and were still further increased in 1793 by the war, which at the same time greatly interrupted their trade, and subjected them to depredations. In October 1794, the colony was attacked by a French Squadron, and all the moveable property of the company was either carried off or destroyed, every building belonging to them burnt, and several ships captured. The company's loss on this occasion has been estimated at 52,000 *l*. This calamity, combined with their previous expences, so greatly diminished the company's funds, as to lay them under a necessity of contracting their trade, and reducing considerably the scale of their establishment, which had been at all times so limited as scarcely to afford sufficient means of transacting the business and attending to the various wants of an infant settlement.

In the year 1798 the colony had made considerable progress, notwithstanding the many obstacles to its advancement. The town consisted of about three hundred houses, with the necessary public buildings, and had become a place of considerable resort. It was estimated that from one to two hundred natives visited the settlement every day, many of them coming from a distance of eighty or a hundred miles, for the purpose of exchanging articles of African produce, for British manufactures. The total number of inhabitants of the colony at this time was about 1200.

In 1800 the company obtained a charter, creating their settlement an independent colony, and authorizing the directors to frame laws for its government, to appoint a governor and council, and to make other arrangements for the administration of justice; a small military force was at

the same time sent for the defence of the colony. The sum of 7000 *l*. being part of the sum granted by parliament for the maintenance of African forts, was paid to the company for the erection of a fort; 10,000 *l*. was about the same time received from government as a partial indemnification for the expence to which the company had been put in settling the Nova Scotians; 4000 *l*. was also granted for the support of the civil government of the colony. About this time the company agreed to receive in their colony the Maroon Indians, and soon after their arrival, employed them to quell an insurrection among the Nova Scotians, who had endeavoured to possess themselves of the government. A more serious attack on the colony was afterward made by some of the native chiefs in the neighbourhood, which rendered it necessary to adopt additional means of defence.

The sums since granted by parliament for defraying the charges of the civil establishment of the company, and for the erection of fortifications, have been as follow:

For the year	1801	£ 4,000
	1802	10,000
	1803	14,000
	1804	14,000
	1805	14,000
	1806	18,000

The trade of the company appears to have been successful, supposing it to have been burthened only with those charges which are strictly commercial, and to have been exempt from the extraordinary losses by fire, and the destruction of the settlement which it has had to sustain. The abolition of the slave trade will remove some great obstacles to the success of this laudable undertaking, and probably enable it to improve and extend its commercial intercourse with the natives very considerably.

COMPANY, *for the Manufacture of Flour, Meal, and Bread*. During the distress occasioned by the great scarcity of corn, in the year 1800, a number of persons formed themselves into a company, for the purpose of establishing in London a manufactory of flour, meal, and bread, to be sold out at reasonable prices. They were incorporated by parliament, and empowered to subscribe a joint capital, not exceeding 120,000 *l*. in shares of 25 *l*. each; their profits being limited to 10 per cent., and the surplus, if any, to be at the disposal of parliament. They were limited to sell only 120,000 sacks of flour, or meal in a year, to make only 200 sacks into bread in a week, and to sell not more than 1000 quarters of wheat in any one week. The managers of the company were prohibited from dealing in corn, flour, or bread, for their own private account; and were required to lay before parliament an annual statement of their receipts and payments, of the quantities of grain purchased, with the prices paid for the same, of the quantities of grain and flour in store, of the quantities of flour and bread manufactured by the company, and of the debts and credits of the company, with the names of all the members of it, and the number of shares held by each. By these regulations sufficient publicity is given to the concerns of the company to prevent it from ever being perverted from the original principle of the establishment, and made subservient to schemes of monopoly or speculation; and though upon the scarcity ceasing, they discontinued making bread, they have carried on the manufacture of flour and meal, and probably contributed to prevent these essential articles from being unnecessarily enhanced in price.

The total quantity of wheat purchased by the company in the year 1806, was 9182 quarters, for which they paid 32,655*l.* 19*s.*; the quantity of flour manufactured was 10,536 sacks. The number of proprietors of the company was 330.

The king by an order in council may dissolve this company on six months previous notice being given.

COMPANY, *Dock*. See DOCK.

COMPANY, *Dutch East-India*, had its rise in the midst of the struggle which that people had for their liberty; for the Spaniards having forbid all commerce with them, and shut up all their ports, necessity inspired some Zealanders to seek a new north-east passage to China.

This enterprize proving unsuccessful to three several armaments in 1594, 1595, and 1596, a second company was formed under the name of the "Company of remote Parts;" which, in 1595, took the ordinary route of the Portuguese to the Indies, and returned in two years and a half's time, with little gain, but good hopes.

This company, and a new one just established at Amsterdam, being united, equipped other fleets; and these occasioned other companies at Amsterdam, Rotterdam, in Zealand, &c. inasmuch that the states soon began to apprehend they might be prejudicial to each other. Under this concern they called all the directors of the several companies together, who all consented to the union, the treaty whereof was confirmed by the states in 1602, a very remarkable epocha, as being that of the most solid and celebrated establishment of commerce that ever was in the world.

At this time they obtained a charter from the states; and prevailed upon that body, by administering to its exigencies in the Spanish war, to grant them the exclusive privilege of trading to the southern parts of Africa, for a short term of years. The company's capital of 6,500,000 florins (about 541,833*l.* sterling) was divided into transferable shares, or *actions*, as they are called on the continent, of 3000 florins (about 250*l.* sterling each), which were all speedily bought up. The superiority of their trading capital, together with their greater skill in commerce and navigation, enabled them to undersell all other nations, even in the foreign markets of Europe. As they also fixed the prices of their merchandize to all consumers, their profits for some years were enormous. The annual dividends for the 6 years ending in 1610 were as high as 36 per cent.; and in a short time, the actions rose from 3000 to 15,000, and at one time stood as high as 24,000 florins, 8 times the amount of their prime cost. The charter, first granted in 1602, and since renewed from time to time, conferred upon them, besides the exclusive right of trading to the East, the sovereignty (under the superintendence of the states-general) of all the territories which they might acquire in that part of the world, by purchase, treaty, or conquest, with the full power of appointing their own servants; of raising whatever force they might deem necessary for the defence of their territories; and of enacting laws for the internal administration of their dominions. In consequence of this charter, the most extensive that was ever granted to any trading corporation, the company proceeded to arrange their establishment, both in Europe and the East Indies. Their affairs were under the management of sixty directors, divided into several chambers; twenty in that of Amsterdam, twelve in that of Zealand, fourteen in that of Delft and Rotterdam, and a like number in those at Sluys and Horn. As each grant expired the company was obliged to procure a new one, which it has already done, four times since the

first; viz. one in 1623, for forty-one years, like the first; another for twenty-one years, commencing in 1643; and a third in 1663, for forty years; a fourth in advance, commencing in 1698, to end in 1740. Each grant cost the company a considerable sum; that of 1647 cost 1,600,000 guilders, and the two following ones more; that of 1698 was confirmed by a placard of the states general, granted them an exclusive privilege, which was prolonged in 1761, for thirty years more. The average premium paid for these renewals was about 270,000*l.* sterling, or three millions of florins.

Their factories, residences; &c. in the East Indies, were very numerous; reaching from the Persian gulf to the coast of China: the principal was that of Batavia, the centre of their commerce: here resided the general, with the state and splendor of a sovereign prince; making war and peace with the eastern kings and emperors at pleasure. They had also several other considerable factories on the coast of China, in Japan, Malacca, Surat, Amboyna, Banda, Siam, Moluccas, &c. several on the coast of Coromandel, and at Ispahan, Cape of Good Hope, &c. in all, they numbered forty factories, and twenty-five fortresses. They engrossed the whole trade of the spicery in their own hands.

At so early a period as the year 1616, this company had no less than 45 large vessels engaged in war and trade, with 10,000 soldiers and sailors in their service, and 4,000 pieces of artillery. However, the flourishing state of their affairs was of short duration. The mismanagement and plunder of the company's servants, and the disputes in which their cruelties, avarice, and imprudence involved them with the native powers during the 17th century, and the dissensions which arose among the different chambers of the general direction at home, greatly reduced the trade, wealth, and power of the institution. The expence of the military establishment also increased; so that at the end of the 18th century, it amounted to 80 vessels, carrying from 30 to 60 guns, and 25,000 men, soldiers included, while the whole dominions in Java, and its dependencies, were farmed for 361,260 dollars. The directors acknowledged that, in 1780, their loss in the war had exceeded 10 millions of florins, nearly twice the amount of their original capital. In the 18th century the Ostend East India company excited the jealousy of the Dutch company. In 1721, a law was passed by the states, prohibiting their subjects from sailing under the Ostend colours, upon pain of death: and in 1731, this unfortunate association was dissolved in consequence of representations from the different European states interested in the East Indian trade; among which Holland, that is the Dutch company, took the lead. Various precautions have been used to support the credit of this company, some of which were oppressive to the country; nevertheless, its shares have continued to fall with augmented rapidity. In the period from 1605 to 1779, the dividends have varied from 75 to 10 per cent.; and in many years no dividend at all was issued. From 1605 to 1610 (both inclusive), the dividend was, at an average, 36 per cent. From 1610 to 1648, the average was only 21; and from 1771 to 1780, it was no more than 12½ per cent. The price of the actions, which had at first risen to 500, and even 800 per cent. of the prime cost, fell, in the period from 1770 to 1780, to about 340 per cent., and during that time continued regularly to fall. The last dividend this once flourishing company made to their proprietors was in the year 1796; but it was not paid till 1799, as their commerce, which had been rapidly declining for the last 30 years, was entirely suspended.

COMPANY, *Dutch West India*, was established in 1621, with an exclusive privilege to trade twenty-four years along the coasts of Africa, between the tropic of Cancer and Cape of Good Hope; and in America, from the south point of Newfoundland, through the straits of Magellan, that of Le Maire, or others, to the straits of Anian, both in the north and south Sea.

Besides these commercial privileges, the states conferred upon the corporation the right of governing and defending any new colonies which it might acquire; and made it a present of several large vessels, well manned. They retained to themselves, however, the nomination of the company's governor-general abroad. The original capital of this association amounted to 72,000 florins, in transferable shares, or actions, of 6000 florins each.

The 74 directors were divided into five chambers (as in the East India company), out of which, eighteen, with a deputy appointed by the states, were chosen for the general direction of affairs. In 1647, the company renewed its grant for twenty-five years; but it was scarce able to hold out the term, on account of its great losses and expences in taking the bay of Todos los Santos, Fernambuc, and the greatest part of Brasil, from the Portuguese. The weakness of this company, which had several times in vain attempted to be joined to that of the East Indies, occasioned its dissolution at the expiration of its grant.

In 1674, a new company, composed of the ancient proprietors and their creditors, was settled in the same rights and establishment with the former. It was to undertake the burden of the old company's debt, amounting to six millions, but reduced to 30 per cent.; and was to accredit in its books the proprietors of the old company's stock, at the rate of 15 per cent. The creditors, on their part, were to advance an addition of 8 per cent. on their loans; and the stockholders were to advance 4 per cent. on their shares. The new capital, thus scraped together, amounted only to 630,000 florins. The exclusive commerce of the company was limited to a certain part of the African coast, besides the conquests they should make; and its principal establishments were at Cape Verd, on the Gold Coast, at Tobago, Curassoa, &c. in America. The rest of the trade monopolized by the former company was now thrown open to all the subjects of the republic. In 1730, when the charter was renewed, the African slave-trade was made free, on condition of a certain lastage being paid to the company; and in 1734, the whole African trade was laid open upon the same terms. As the united privileges of the company were not sufficient to counterbalance the various disadvantages under which all fresh institutions labour, they obtained, in 1682, the exclusive management of the colony of Surinam, for the trifling sum of 260,000 florins paid to the states-general. This grant was accompanied by certain conditions, framed with the manifest view of preventing the abuses common to trading corporations. Under these restrictions, the company was not able to defray the expence of the original purchase-money paid for the charter; and, therefore, in the next year, one-third share was sold to the city of Amsterdam, and another to the rich family of Sonmelsdyk, reserving the remaining third to themselves. These three co-proprietors have since continued to form a society or partnership, under the name of the "Surinam Company," regulated by the charter originally granted to the West India company. Except in the government of Surinam, this association has had no connection with the West India company, which, of course, continued to furnish negroes to the settlement, in its capacity of African company, until the year 1730.

The progress of the dividends and prices of West India stock will enable us to judge concerning the prosperity, not only of the Surinam society, but also of the concerns of the West India company. The average dividend in ten years, ending 1690, was 2½ per cent.; and from 1773 to 1779 inclusive, nothing at all was divided. The actions have never been at par; their price has varied from 92½ to 18 per cent. since the year 1723. The average price during ten years, ending 1732, was about 81½ per cent. During ten years, ending 1779, it had fallen to 32½ per cent. The settlements of Essequibo and Demerary have been always under the charter of the West India company, as well as Surinam, and governed in the same manner. Berbice, though within the company's charter, owed its origin to the speculations of the family of Van Peere; and all the cultivated part of the colony belonged to them. In 1678 they obtained a perpetual grant of it from the company, which was confirmed in 1703; and when the French attacked it in 1712, the colony bought them off with a considerable composition. The money was paid by their great mercantile houses, and one fourth of it by the Van Peeres, who thus transferred three-fourth shares of the colony to the other merchants as co-proprietors; and the four houses together formed a copartnership or company at Berbice, administered exactly in the same manner with the Surinam society. The proprietary governments of North America differed from the company administrations of Guiana in many important particulars. They were the consequence of large and thoughtless grants, made by the court to favourites, of waste and uninhabited lands. As the British colonies were subservient to the legislature of the mother-country, the Dutch colonies owed the same allegiance, not to the states-general, but to the proprietors. The ill success of the West India company furnishes an useful example of the manifold evils of company government. This company must of late have been annihilated by the capture of all their settlements.

COMPANY, *Dutch North*, has no exclusive privilege; the advantage of its patent being of another kind, and very considerable.

There are also, in Holland, companies for the Baltic sea, the fishery of Nova Zembla, Davis's Straights, and Greenland: yet none of their fisheries are interdicted to private traders; all the difference between these and the companies consisting in this, that the former may not go ashore to cut their fish in pieces, and melt their lard: but must bring their luggage to Holland.

COMPANY, *Dutch Levant*. In strictness, there is no Levant company in Holland: but the commerce of the private traders is so considerable, that the state has taken the regulation thereof on itself.

To this end, they have established a chamber of direction at Amsterdam, composed of six deputies, and a register; who, under the burgomasters, take care of every thing relating to the commerce of the Mediterranean; especially that of Smyrna and Constantinople.

This company names the consuls, appoints the number and strength of convoys, terminates differences among the traders, and has also a right, on occasion, to add new regulations to the old ones; though those be of no force, till confirmed by the states general.

COMPANY, *French East India*, was established in 1664, with an exclusive privilege to trade for fifty years in all the seas of the East Indies and South Sea; no adventurer to be admitted without a thousand livres in stock; and foreigners, who have twenty thousand livres in stock, to be reputed renegicoles.

The patent grants them the island of Madagascar; and

the king to be at one fifth of the expence of the three first armaments, without interest; the principal to be refunded in ten years; or, if the company finds it loses on the whole, the loss to fall on the king's side.

The capital fund of the company, which was mostly furnished by the king, was seven or eight millions of livres, but was to have been fifteen millions.

In effect, though no means were wanting to support the company, yet it still drooped, and still struggled; till, having subsisted ten years without any change in its form, and being no longer able to discharge its engagements, there were new regulations concerted, but to little purpose. At length, things not being disposed for a new East India company, nor much good to be expected from the old one, in 1708, the ministry allowed the directors to treat with the rich traders of St. Malo, and resign to them their privilege under certain conditions. In the hands of these last, the company began to flourish.

Its chief factory was at Pondicherry, on the coast of Comorandel; this was the residence of the director-general; the other factories were inconsiderable. The merchandizes which the company brought into France were, silks, cottons, spices, coffee, rice, salt-petre; several kinds of gums and drugs, wood, wax, printed calicoes, muslins, &c. The trade was laid open in 1769, which soon reduced the company to a set of mere holders of the government funds. A new company was established in 1785 with the privilege of an extensive trade to all parts of the East Indies, except the Isle of France and its dependencies. This exception must have prevented the company from succeeding; but the experiment had scarcely been made when the trade was again laid open by the national assembly in 1790. As for the other French companies, such has been the state of the country, they are all, we presume, extinct; and it is needless to give any account of them. Such were the *French West India company*, established in 1664, and possessing by their charter the property and seigniority of Canada, Acadia, the Antilles island, the isle of Cayenne, and the Terra Firma of America, from the river of the Amazons to that of Oroonoko; with an exclusive privilege for the commerce of these places, as also of Senegal, and the coasts of Guinea, for 40 years, on condition of paying half the duties; but in 1674 the grant was revoked, partly on account of the poverty of the company, and partly because it had answered the purpose of its establishment by recovering the commerce of the West Indies from the Dutch:—the *French Mississippi company*, first established in 1684, in favour of the chevalier de la Salle, who failed in search of the Mississippi, but miscarried with his colony, and came to an untimely death. He was succeeded by M. Hiberville, who found the Mississippi and settled a colony there; but this adventurer being poisoned, M. Crozat obtained in 1712 the sole privilege of trading to the French territories called Louisiana, granted to him for 15 years:—*Company of the West*, formed in 1717, when M. Crozat surrendered his grant before mentioned; and obtaining besides every thing granted to the former company the commerce of beaver, enjoyed by the Canada company from the year 1706, but expiring in 1717:—*India company*, formed by a junction of the former company with that of Canada and with that of Senegal in 1718, and also by an union with the East India company, and with those of China and St. Domingo, with the two first in 1719, and with the third in 1720:—the *Bastion company*, arising from the association of two merchants of Marseilles

in the 15th century for fishing of coral in the gulf of Stora-Courcoury on the coast of Barbary, on the frontiers of Algiers and Tunis; so called from a small fort called the "Bastion of France," built in 1561, but it sunk in 1633;—and several other companies, which either fell of themselves, or upon the expiration of their grants, and which it is therefore needless to mention.

COMPANY, Danish North, was established at Copenhagen in 1647. Its establishments are very considerable in Norway; besides which, it sends vessels to Waranger, whence they convey their merchandizes by land into the Danish Lapland; and by sledges drawn by rein-deer into the Muscovite Lapland. It also sends others for Borondai and Siberia; where its agent takes them up, and conveys them, in like manner, on sledges, to Panigoro, the capital of this part of the Muscovite empire.

The commodities it sends thither are rix-dollars, tobacco, and linens; it returns nothing but furs and skins.

COMPANY, Danish Iceland, established in the same year with the North Company, its chief factory is at Kirkebar, a large town in that island.

COMPANY, Danish East India, established in the year 1616, and invested not only with the exclusive privilege of trading to the East, but with the powers of civil and military administration; their chief factory was at Tranquebar. In 1634 this corporation was dissolved, and another, with similar privileges, substituted in its place. This also rapidly declined; and in 1686, a third institution was tried for the same purposes; but this too failed in about 23 years; and the project was tried for the fourth time in 1732. The new company was provided with ample privileges and powers; and the possession of these preserved its existence, and increased the profits of the stock-holder, at the expence of the country, and of the Indian settlements. In 1772 the charter expired, and was renewed under restrictions which proved ruinous to the prosperity of the company. In 1777, the king purchased the rights of the company, and the private trade began to flourish. When the charter was renewed in 1792 for 20 years, the private trade was rendered still more free; all Danish subjects, and all foreigners were permitted to trade with the Indian settlements, upon receiving passports, either from Copenhagen or the Asiatic seats of government, and upon condition of returning with the cargoes to Copenhagen.

COMPANY, Levant, of the Genoese, established in 1664, and confirmed by the Pope; notwithstanding the opposition of the French. From 1670 this company has languished and sunk.

For a more particular account of the rise and progress of most of the above mentioned and other companies, see "Anderson's Hist. of Commerce."

COMPANY, New River. This corporation consists of a governor, deputy governor, treasurer, and twenty-six directors, who hold a weekly board for appointing officers, granting leases, and redressing grievances. The projector of this canal for bringing water to London, with the assistance of king James I. and the corporation of London, is supposed to have expended 50,000*l.* upon it: the profits, which are divided into seventy-two shares, for the first thirty years admitted of little more than five pounds to each share; but their value is much increased, and its original shares of 100*l.* are now estimated at upwards of twelve thousand pounds each.

Condensation

CONDENSATION (from *condensate*, and *condensate* from the Latin *condensatus*), denotes the contraction of a given quantity of matter into a smaller space, and in this sense only the word condensation ought to be used; however, in common language, the inspissation, the thickening, or hardening of certain compound substances, in consequence of the escape of some of their component ingredients, is frequently expressed by the same term; thus the juices of fruit, of plants, of meats, &c. are often said to be condensed over the fire. Compression and condensation (though sometimes used the one for the other) differ in this; *viz.* that the former denotes a diminution of bulk, occasioned by the application of external force; whereas the latter expresses the same effect, when produced without that external application, as is the case with most bodies in cooling. But the word condensation has been more commonly used for denoting the conversion of vapour into water, or of vapours in general into liquids.

The particulars which might be noticed with respect to condensation are, the quantity and rate of contraction in different bodies, the causes which produce it, and the limits of that contraction. These particulars, however, will, with more propriety, be stated under the articles EXPANSION, THERMOMETER, and PYROMETER, which see.

Notwithstanding the above-mentioned definition, it is to be remarked, that in every case of condensation, or of the contraction of a body into a narrower space, the effect is produced by the escape of something; and in bodies, which seem to be the simplest in nature, the contraction which they undergo in cooling, is occasioned by the escape of the caloric, which the present state of philosophical knowledge reckons amongst the elementary substances. But the reverse of this proposition is not always true; *viz.* bodies are not always contracted in their dimensions when the caloric escapes from them; and such has been found to be the case with water, with iron, and with some other substances, in certain temperatures. This will be rendered more evident in the sequel.

Most bodies are susceptible of three successive states of existence; namely, the solid, the liquid, and the elastic or vaporous; and all these are effected by the introduction of different doses of caloric. During every one of those states, a different degree of condensation is produced by the intermediate gradations of temperature; *viz.* such as are not quite sufficient to induce a different state of existence in the body concerned. Thus, a quantity of the vapour of water, which, at the temperature of 242° (Fahrenheit's thermometer), and under the mean gravity of the atmosphere, occupies the space of 3600 cubic inches; if it be gradually cooled until the temperature becomes equal to about 212° , its bulk will be contracted so as to occupy the half of the space it did before, *viz.* about 1800 cubic inches. If the temperature be lowered below 212° , the vapour will be condensed into liquid water, which will occupy the space of not more than a single cubic inch. If the cooling be continued, the water will be contracted in its bulk, but not very regularly (that is, the decrements of bulk will not be exactly proportional to the decrements of heat); until the temperature descends to about 42° . Below that degree, the water,

instead of contracting its bulk, is expanded by further cooling; *viz.* by a further abstraction of caloric. This is a very remarkable property of water, upon which some interesting phenomena of nature are depending. The water, though expanding below the temperature of 42° , still continues fluid as far as about the temperature of 32° ; but below this last mentioned point, by farther cooling it becomes a solid; namely, ice; and in this state water occupies a greater space than it did in a liquid state. (See CONGELATION.) Similar irregularities have been observed in the condensations of several other bodies, both solid and fluid; and it is to be wished that experiments capable of determining the laws of condensation were instituted with all those bodies which are at all susceptible of the trial.

The causes of condensation are by no means thoroughly understood. It may seem, at first sight, sufficient to say, that since caloric is an elementary substance, which is combined in various proportions with every other known body, the separation of part of that element from the other bodies, naturally enables the particles of the latter to come closer to one another in virtue of their mutual attraction. But that this cannot be the sole cause of the condensation in its whole extent, is easily pointed out by the following queries. 1st. How are the particles of bodies disposed, that they may be capable of approaching, or of receding from each other? 2dly, Why the degrees, or quantities, of condensation are not always proportional to the degrees of caloric that are abstracted from bodies? And, 3dly, Why clouds, fogs, mists, &c. (which consist of the vapour of water suspended in the atmosphere) are not always condensed into liquid water below the temperature of 212° ; which is actually the case in the atmosphere?

It has for a long time been an opinion prevalent amongst philosophers, that the particles of bodies do not actually touch one another; for otherwise it seemed impossible to comprehend how a body could be expanded and condensed. But the least consideration will easily suggest a variety of dispositions of the particles, which, whilst they actually touch one another, will readily admit of the dilatation and condensation of the aggregate. Conceive, for instance (as professor Prevost of Geneva justly observes), the particles to be elongated, and united at their extremities like the legs of a pair of compasses, and they may turn, with regard to this point of union, as a centre, and produce condensations and dilatations of the whole apparent mass of the body. A sponge likewise will dilate in water without interrupting the continuity of its parts. One may also conceive the particles of bodies arranged in the form of rings; that is, many of them to be in absolute contact, one with the next, and this with the following, &c., so as to form circular or oval rings. With this disposition of particles, the dilatation and condensation of the aggregate is nothing more than an alteration of the form of those rings; *viz.* they become more like circles when the body is expanded, and more oblong when the body is condensed; it having been demonstrated by mathematicians, that the circle comprehends an ampler space than any other figure of the same periphery. Though the general disposition of the particles of a body is not known, yet a va-

riety of phenomena clearly indicate that they are not confusedly placed; but that some arrangement, probably a peculiar one, for the particles of each different body, actually takes place; and to this peculiar arrangement some of the effects of dilatation and condensation, at least the irregularities of those alterations, must undoubtedly be attributed. Thus the particles of water crystallize in freezing; that is, they dispose themselves with a peculiar regularity, somewhat resembling the filaments of a feather. These filaments of water form angles of about 60 degrees with a larger filament, which is, as it were, the stem of the feather; and to this crystallization the enlargement of the bulk of water in freezing is with propriety attributed. Such is the force with which the particles of water endeavour to arrange themselves in that particular order, and of course to enlarge the bulk of the aggregate, that several astonishing effects are produced by their united efforts. Pieces of timber, stones, and other bodies, are burst by the freezing of inclosed water. Even iron mortar-shells, such as are used in war, filled with water, and accurately stopped, have been burst by the freezing, and the consequent enlargement of the inclosed water.

Since the enlargement of the bulk of water commences at about the temperature of 42°, which is 10 degrees above the point of melting ice, commonly called the *freezing point*, which is 32°, it is evident that the particles of water begin to arrange themselves in a particular order long before the freezing takes place. And, by following the analogy, it may be supposed, that in every state of existence the particles of bodies have, more or less, a tendency to arrange themselves in a certain order; to which tendency the irregularities in the condensations of bodies are probably to be attributed.

The above-mentioned particulars, respecting the condensation of water, must in great measure be understood to belong to a great variety of bodies; for all those which have been subjected to decisive experiments have been found to contract or to enlarge their bulk with irregularity, in some part at least, if not throughout, the whole scale of heat.

The condensation of vapour in the atmosphere, which is not always accompanied with a proportionate degree of temperature, forms another difficulty, which the present state of philosophical knowledge is not entirely capable of explaining. We shall, however, briefly state certain facts and certain considerations, which ought to be kept in view by those who are willing to investigate this intricate and interesting

subject. The conversion of water into vapour is attended with an increase of its capacity for containing heat, or caloric, and likewise with an increase of its capacity for containing electric fluid; so that if a quantity of water, held in an open and insulated vessel, be suffered to evaporate, the vapour will deprive the vessel of part of its heat, and of part of its electric fluid: consequently, the vessel will be cooled and electrified negatively. Now that which philosophers wish to ascertain is, whether the influx of the caloric and of the electric fluid produces the evaporation, or the conversion of the water into vapour draws the caloric and the electric fluid from the contiguous bodies. In the first case, we see no reason why the caloric and the electric fluid should spontaneously quit the contiguous bodies, and run to the water in order to force it to evaporate, because both the water and the contiguous bodies are in an equilibrium; that is, in the same state with respect to temperature as well as of electricity. In the second case, if the influx of heat and of electricity does not force the water to evaporate, what other cause can produce that effect?

The same reasoning which has been applied to the conversion of water into vapour, may, *mutatis mutandis*, be adapted to the contrary effect; viz. to the condensation of vapour into water, it being equally difficult to comprehend how the vapour can remain in the elastic state, that is, without being converted into water, at a temperature much lower than 212°, which in the atmosphere is generally the case. There is one consideration, however, which may throw some light upon this remarkable phenomenon; viz. that in order to deposit the caloric and the electric fluid, which must necessarily take place in the condensation of vapour, there must be a body or bodies ready to receive both. But in the atmosphere, the only body which can receive them is the air, and it is well known, that air is a bad conductor of heat as well as of electricity. The last remark which we have to subjoin is, that it has been observed with several substances, and especially with water, that though placed in a colder temperature, they do not part with their caloric so easily as it might be expected, and this is particularly the case when they are to undergo a change in their state of existence; thus water will sometimes continue fluid when its temperature is 4 or 5 or even more degrees below 32°; though when once formed into ice, this will not melt at a temperature lower than 32°, and yet it will evaporate if exposed to the air whilst its temperature is many degrees below 32°.

Condenser

CONDENSER, from *condense*, is an instrument capable of collecting, or of drawing into a smaller space any scattered matter, or quality, or effect. In philosophy and in mechanics, three different instruments have obtained the name of condensers; viz. the *condenser of air*, the *condenser of electricity*, and the *condenser of forces*.

The *condenser of air*, in pneumatics, is a syringe, by means of which a considerable quantity of air may be forced into a vessel fitted for the purpose. Fig. 1 and 2, *Plate XIV. Pneumatics*, represent two constructions of this sort of condenser, which differ but little from each other. They are generally made of brass or of iron. A B, *fig. 1*, represents a cylindrical tube, at most, two inches in diameter, and from 8 to 12 inches in length, or even longer. Its flat bottom B is perforated with a hole, on the outside of which, a valve, (consisting of a piece of oil silk, or rather of leather, stretched over a small flat piece of brass), is adapted, so that if any air be forced from the inside of the cylinder A B, that fluid will easily lift up the valve, and make its exit through the hole at B. But should any suction take place within the cylinder A B, the air cannot possibly enter through the hole at B, because the valve on the outside prevents it by stop-

ping that hole. The piston *c d* fits the cavity of the cylinder A B pretty tightly, by means of leathers soaked in oil; and it may be moved up or down by the handle E which is fastened to its rod. This piston is perforated with a hole *c d*, the lower part of which is furnished with a valve *d*, which, when the piston is drawn upwards, will permit the air to enter the lower cavity of the cylinder; but if the piston be pushed downwards, the air which is contained in the lower cavity of the cylinder, cannot pass through the hole *c d*, on account of the valve at *d*; therefore it will come out through the hole at B. At the extremity of the cylinder, a brass or iron cap F G is screwed over the valve, allowing however a little room for its free motion. The end G of this cap is perforated quite through, and its outside is formed into a screw.

Fig. 2 represents a condensing instrument simpler than the preceding, and such indeed is at present mostly used. Neither the cylinder nor the piston of this instrument is furnished with any valve. There is a hole through the screw at the bottom B of the cylinder, and a hole at C through its side, and at about two or three inches below its upper end; the piston has no perforation.

When the condenser, *fig. 1*, is screwed into the aperture of a glass or metal vessel, and the piston is moved alternately up and down, it will be readily understood, that the air will be forced into the vessel to which the condenser is adapted; for when the piston is pulled upwards, that is, towards A, the air cannot enter the cylinder through the hole at B, but it can easily pass through the hole *cd*; and when the piston is pushed in, the air which is contained in the cavity of the cylinder, cannot go out of it through the hole *cd*, but it can pass through the hole at B; hence it is forced to enter the vessel to which the condenser is applied. Thus by repeating the movements of the piston, more and more air is condensed into the vessel, until the latter is burst by the elasticity of the condensed air, or the same force pushes so hard against the valve at B, that the strength of the operator is no longer able to overcome it. The condenser, *fig. 2*, is used exactly in the same manner; this, however, must be adapted to such vessels as are furnished with a valve within their aperture, which permits the entrance, but not the exit of the air. When the piston of this condenser is drawn towards C, a vacuum is formed in the lower part of the cylinder, until the lower part of the piston is raised above the hole C; then the air rushes through that hole, and instantly fills the cavity, &c.

These instruments are generally used for condensing the air into the air-holders of wind-guns, of certain water fountains, and other machines. By this means, the air has sometimes been condensed to such a degree, as to become six, eight, and even more times, denser than common atmospheric air. The vessel, in that case, is said to contain respectively six, or eight, or a greater number of atmospheres.

In a variety of philosophical experiments, substances are frequently placed in a glass vessel in which air is condensed, in order to observe its effects upon the enclosed substances. For this purpose, one of the above-mentioned condensers is affixed to a frame and apparatus, as is represented in *fig. 3*; and this apparatus, all together, is called a *condensing engine*.

CD is a brass condenser, which is worked by applying the hand to the handle Z of the piston, and by moving the latter alternately up and down, the air is forced through the brass pipe DNF into the glass receiver AB. This receiver, which must be very thick and well annealed, is set with its smooth and flat edge upon the brass plate of the machine, which is similar to the plate of an air-pump. A thick piece of brass LM, is applied in a similar manner to the upper aperture of the glass receiver, and a slip-wire passes through a collar of leathers in this brass piece. In order to prevent the lifting up of the brass piece LM from over the glass vessel, or the latter from the plate on the frame of the machine by the force of the condensed air, two pillars of wood with a cross piece GH, likewise of wood, are annexed, for the purpose of keeping down the glass vessel, and the piece of brass LM. The cross piece GH is pressed upon LM by means of the screw-nuts on the pillars I, K. There is a gage EF, annexed to this machine, which indicates the condensation of the air within the glass vessel, and tube of communication. It consists of a strong and narrow glass tube, hermetically closed at E, and connected with the brass tube of communication at F. A small quantity of mercury fills up a short part of the cavity about the middle of the tube, and the space between the mercury and the closed end E of the tube, contains air of the usual atmospheric density. It is by the contraction of this small quantity of air, that the degree of condensation in the glass receiver is indicated; for in proportion as the air is condensed into the receiver, or tube of communication, &c., so the air between

the mercury and the closed end of the gage becomes contracted more and more; and the quantity of that contraction is indicated by a scale annexed to the glass tube; for instance, if that air is, by working the machine, compressed into the half of the space it occupied at first, it shews that the air within the receiver is as dense again as it was before the working of the machine. If the air in the gage is compressed into a quarter of its original space, the air within the receiver is shewn to be four times as dense as it was before the working of the machine, and so forth; the condensations in the glass receiver being inversely as the spaces occupied by the air in the extremity E of the gage. These degrees of condensation are commonly expressed by saying, that the receiver contains two, or three, or four, or more atmospheres, when the air within it, is twice, or three times, or four times, or more times, denser than the usual air of the atmosphere.

There are certain air-pumps, as those of Smeaton, of Haas and others, the construction of which renders them capable of being used for condensing, as well as for exhausting the air. See AIR-PUMP. In certain forcing water pumps, in fire engines, and some other hydraulic machines, there is a vessel, in which the air is condensed by the action of the machine itself; the object of which is to produce a constant stream of water out of the engine, whilst the piston of it is moved up and down in the usual way. This vessel is called the *air vessel*, and often the *condensing-vessel*, or simply the *condenser*. See PUMP, and FIRE-ENGINE.

The head of an alembic, wherein the vapours are condensed into a liquid, has sometimes been called the *condenser* of the alembic.

CONDENSER of Electricity. This is an instrument capable of collecting, or of condensing into a small space, such quantities of weak and diffused electricity, as would otherwise remain unperceived, or be insufficient to affect even the most sensible electrometer. It was originally invented by a very distinguished philosopher, Mr. Volta of Como, and is by himself described in the 72d vol. of the Philosophical Transactions. But, since its original invention, this instrument has undergone several improvements and alterations, which we shall now describe, together with their peculiar advantages and defects.

The action of electric atmospheres is the principle which suggested the construction of this most useful electrical instrument. Though the nature of these atmospheres will be treated of in the article ELECTRICITY; it will, nevertheless, be necessary to give, in this place, some idea of their action, by means of an easy experiment, in order to render the principle upon which the electrical condenser acts, manifest to the reader. Affix an electrometer of pith-balls to an insulated metallic plate; that is, a plate of tin or brass, or other metal, having a glass handle. Communicate some electricity to it, and observe the divergency of the electrometer. In this state, bring the electrified plate near a conductor which is not insulated, such as the wall of a room or another metallic plate, and you will find that the electrometer collapses in proportion as the electrified plate comes near to the uninsulated conductor. Remove the electrified plate, and the electrometer will diverge again, nearly as much as it did at first; which shews, that by the vicinity of the uninsulated conducting body, which could easily acquire the contrary electricity, the intensity of the electricity in the electrified plate was diminished; or, which is the same thing, that the capacity of that plate for containing electricity was increased. Hence, when an insulated metallic plate is situated near another metallic plate not insulated,

the former will thereby be enabled to absorb a much greater quantity of electricity than it otherwise would, from any source whatever; and if the electrified plate be removed from the other, then that absorbed electricity will be manifested by the divergency of the electrometer, or even by affording a spark. It naturally follows, that according as the conductor which is opposed to the insulated plate, is nearer to, or farther off, so the capacity of the plate will be increased more or less. Such an insulated plate, placed upon an imperfectly insulating, or an imperfectly conducting plane, for the purpose of collecting weak and scattered electricity, was called a *condenser* by Mr. Volta. The reason of using an imperfectly conducting, or imperfectly insulating plane, is, that when the insulated condensing plate is placed upon it, the electricity will not pass from the latter to the former. In short, the following particulars should be attended to in the construction of this, Mr. Volta's, condenser. The metal plate should be about six inches in diameter, with the edge well rounded, and furnished with a varnished glass handle. The inferior plane must be of a very imperfectly conducting nature, such as dry marble, very dry and slightly varnished wood, a common piece of wood covered with oiled silk, or such like substance; but be its substance what it may, its surface must be very smooth, and such as to coincide as well as possible with the surface of the metal plate, viz. the receiving plate; on which account, if a marble slab be chosen for the inferior plane, it will be proper to fit the surface of the metal-receiving plate to that of the marble, by grinding one against the other.

The apparatus, consisting of the above described two planes, being properly constructed, lay the receiving plate upon the other plane, connect the former with an atmospheric conductor, not much elevated above a house, or with the vapour of boiling water, or, in short, with any weak source of electricity, such as could not be discovered by any other means, and after a certain time lift the receiving plate from over the other plane, holding it by the glass handle, and present it to an electrometer, which will be caused to diverge sufficiently to ascertain the presence and the quality of the electricity. Sometimes the receiving plate will even be able to afford a spark. Yet, in several cases, the receiving plate is electrified so slightly, as not to occasion the divergency of the most delicate electrometer. A contrivance of Mr. Cavallo, which is described in his *Treatise on Electricity*, (fourth edition, vol. ii. p. 265) rendered this weak state of electricity capable of affecting the electrometer in a very sensible degree. His description of this contrivance is as follows:

"I naturally thought that, for the same reason which enabled the condensing plate of Mr. Volta's apparatus, to manifest such small degrees of electricity as could not otherwise be observed, another smaller plate, or small condensing apparatus, might be employed to collect and to render sensible the weak electricity of the large metal plate. Accordingly, I constructed a small plate of about the size of a shilling, having a glass handle covered with sealing-wax; and when the large metal plate seemed to be electrified so weakly as not to affect an electrometer sensibly, I placed the small plate upon the inferior plane, and touched it with the edge of the large plate; then, after removing the large plate, I took up the small one from the plane, holding it by the extremity of the glass handle, and presented it to the electrometer, which generally was so much affected by it as to diverge to its utmost limits.

"In this manner I have often obtained electricity, more than sufficient to ascertain its quality, from a single stroke of the corner of an handkerchief; viz. the large plate being laid

upon the proper plane, was stroked once with the handkerchief; then, being removed and presented to an electrometer, it appeared not electrified; but by touching the small plate with the edge of it, that small plate acquired thereby electricity sufficient to make an electrometer diverge."

With this condensing apparatus Mr. Volta, and other philosophers, made several discoveries; yet the use of it was not always attended with the desired effect, which was principally owing to the changeable nature of the semiconducting plane, upon which the receiving plate was placed; it being difficult to obtain, and much more difficult to preserve, such plane in a middling or semiconducting state; for sometimes it would carry off the electricity from the superimposed receiving plate, and at other times it was not of a conducting nature sufficient to enable the upper plate to condense the electricity. It, likewise, often happened that this plane would acquire some electricity either in consequence of the slightest friction, or by communication, which rendered the action of the upper plate quite equivocal. With a view to remove these inconveniences Mr. Cavallo contrived an instrument capable of answering the same purpose, but quite free from all the above-mentioned objections. The principle of this instrument is like that of Mr. Volta's condenser; excepting that the receiving plate does not touch the other plane, though it comes very near it, and it likewise opposes another plane to the other side of the receiving plate. Those planes are of metal, and by their not touching the receiving plate, enable the latter to act with certainty and without obstruction. Upon this principle, viz. of the two plates not actually touching, but approaching one another very nearly, the present electrical condensers are constructed, however they may have been varied in size, in name, and in shape. By the aid of these condensers various important discoveries have been made in electricity, and especially in that branch of it, which is called galvanism. The original description of this instrument of Mr. Cavallo, is in the 78th. vol. of the *Philosophical Transactions*, for the year 1788, from which we make the following extracts.

"The properties of this machine, which from its office may be called a *collector of electricity*, are first, that when connected with the atmosphere, the rain, or in short with any body which produces electricity slowly, or which contains that power in a very rarefied manner, it collects the electricity, and afterwards renders both the presence and quality of it manifest by communicating it to an electrometer. Secondly, this collecting power, by increasing the size of the instrument and especially by using a second or smaller instrument of the like sort to collect the electricity from the former, may be augmented to any degree. Thirdly, it is constructed, managed, and preserved with ease and certainty; and it never gives, nor can it give, an equivocal result, as I have proved experimentally, and as will appear by considering its construction."

"The figures 4 and 5, *Plate, II. Electricity*, exhibit this instrument, viz. *fig. 4* shews the instrument in the state of collecting the electricity, and *fig. 5* shews it in the state in which the collected electricity is to be rendered manifest. An electrometer is annexed. The letters of reference indicate the same parts in both figures. A B C D is a flat tin plate, thirteen inches long and eight inches broad; to the two shorter sides of which are soldered two tin tubes, A D and B C, which are open at both ends. D E and E F, are two glass sticks covered with sealing wax by means of heat, and not by dissolving the sealing wax in spirits. They are cemented in

the lower apertures of the tin tubes, and also in the wooden bottom of the frame or machine, at E and F, so that the tin plate, ABCD, is supported by those glass sticks in a vertical position, and is exceedingly well insulated. GHILKM and NOPV, are two frames of wood, which being fastened to the bottom boards, by means of brass hinges, may be placed so as to stand in an upright position and parallel to the tin plate, as shewn in *fig. 4*. or they may be opened, and laid upon the table which supports the instrument, as shewn in *fig. 5*. The inward surfaces of those frames from their middle upwards are covered with gilt paper, X, Y; but it would be better to cover them with tin plates, hammered very flat. When the lateral frames stand straight up, they do not touch the tin plate; but they stand at about one-fifth part of an inch asunder. They are also a little shorter than the tin plate, in order that they may not touch the tin tubes, AD, BC. In the middle of the upper part of each lateral frame is a small flat piece of wood, S and T, with a brass hook; the use of which is to hold up the frames without the danger of their falling down when not required, and at the same time it prevents their coming nearer to the tin plate than the proper limits. It is evident that when the instrument stands as shewn in *fig. 4*, the gilt surface of the paper, X, Y, which covers the inside of the lateral frames stands contiguous and parallel to the tin plate."

"When the instrument is to be used, it must be placed upon a window, a table, or other convenient support, a bottle electrometer is placed near it, and is connected, by means of a wire, with one of the tin tubes, AD, BC; and by another conducting communication the tin plate must be connected with the electrified substance, the electricity of which is required to be collected on the plate, ABCD: thus, for instance, if it be required to collect the electricity of the rain, or of the air, the instrument being placed near a window, a long wire must be put with one extremity into the aperture, A or B, of one of the tin tubes, and with the other extremity projecting out of the window. If it be required to collect the electricity produced by evaporation, a small tin pan, having a wire or foot of about six inches in length, must be put upon one of the tin tubes; so that the pan may stand about two or three inches above the instrument. A lighted coal is then put into the pan, and a few drops of water poured upon it, will produce the desired effect."

"The quantity of electricity, which the tin plate, ABCD, is capable of collecting, principally depends on three circumstances, *viz.* 1st. On the distance between the tin-plate and the conducting lateral surfaces: the smaller that distance is, the greater being the collecting power; 2dly. On the size of the instrument; and 3dly. On the quantity of electricity possessed by the body from which it must be collected or taken away."

"I need not expatiate on the principle upon which the action of this instrument depends; this being the same as that of the electrophorus of Mr. Volta's condenser, and of many other electrical experiments; namely, that a body has a much greater capacity for holding electricity, when its surface is contiguous to a conductor which can easily acquire the contrary electricity, than when it stands not in that situation."

Though this original condenser, which, by way of distinction, its inventor called a collector, answers the purpose for which it was intended perfectly well; yet for the common run of experiments, its size may be dispensed with, as it takes up too much room on the table of an electrician. On this account, not only the size of the instrument has

been reduced, but its shape also has been varied according to the fancy of almost every philosophical instrument maker. For the sake of simplification in the condensers which are at present in general use, one conducting plane only is opposed to the receiving plate, which answers the purpose sufficiently well; for if the electricity collected by the receiving plate happens to be too weak to affect the electrometer, a smaller condenser may be used, which will condense the electricity of the former, &c.

The forms of the condensers that are mostly used at present, are represented in *figs. 6, 7, 8, and 9*. *Fig. 6* exhibits a vertical section of the condenser constructed by Mr. John Read of Knights-bridge; *aa* is a circular flat plate of brass, about eight inches in diameter, standing insulated, by means of the glass stick *f*, on the wooden foot *g*; *gb* is a hollow brass cylinder, terminating in the hollow brass cone *ecdb*; and to this cone the flat perforated brass plate *bccb* is affixed. The glass stick *f*, which, by means of a brass ferril, is fastened to the plate *aa*, has its lower extremity cemented in a cylindrical piece of wood, and this piece of wood is fixed in the bottom *g*. Now it will be easily perceived, by inspecting the figure, that the hollow cylinder *bg* may be moved up or down by sliding it upon the cylindrical piece of wood; and that, by so doing, the plate *bccb* may be brought near to, or removed from the plate *aa*, which is the receiving plate of this condenser; *i* is a milled-head screw, which serves to fix the plate *bb* at a proper distance from *aa*, where a stop is made for that purpose; when *i* is loosened, the plate *bb*, with *cbg*, which is all one piece, falls in the situation represented in the figure, and in that state an electrometer is put in contact with the plate *aa*, in order to manifest the electricity which *aa* condensed whilst *bccb* stood near it.

Fig. 7 represents a condenser of another form, as made by Mr. Cuthbertson. This sort of condenser is both simple in its construction, and commodious in practice; *ab* is a brass plate of about 8 inches in diameter (the instrument being shewn in profile), which is screwed tight into the wooden head *c*, which is cemented on the glass stick *d*, and this is cemented with its lower extremity into the wooden stand *ee* of the instrument; *fi* is a similar plate of brass, fastened to the brass head and pillar *gi*, the lower part of which turns round a pin at *b*, so that it may either stand upright, or it may be inclined after the manner of the dotted representation *hm*. It is almost superfluous to add, that *ab* is the receiving plate of this condenser. *Fig. 8* shews a front view of a condenser of this sort, placed close to a gold leaf electrometer, furnished with a smaller condenser, *viz.* such as is represented by itself in *fig. 9*. The small condenser, *fig. 9*, is similar to the one represented in *fig. 7*; saving that in *fig. 9* the receiving plate is affixed to the cap of a gold-leaf electrometer; so that this apparatus, *viz.* *fig. 9*, may be used by itself in most experiments; but in certain cases it will be necessary to employ the condenser *fig. 7* first, and afterwards the electricity may be farther condensed by means of the apparatus *fig. 9*, as shewn in *fig. 8*.

There is an instrument contrived by Mr. Wilson, which he calls "a compound electrical instrument for condensing and doubling." But as the construction, as well as the principal use, of that instrument properly belongs to another class of electrical instruments, its description will be found in another part of this work. See DOUBLER, and MULTIPLIER of electricity.

CONDENSER of forces. This name was given by Mr. R. Prony to a contrivance for obtaining the greatest possible effect from a first mover, the energy of which is subject to

augmentation or diminution within certain limits; and in general to vary at pleasure the resistance to which the effort of the first mover forms an equilibrium in any machine whatever, without changing any part of their construction. (Bulletin of the Philomathic Society at Paris, No. 83.)

The general problem in mechanics, of which this condenser is intended as a practical solution, is enunciated by Mr. Prony in the following terms:

"Any machine being constructed, to find, without making any change in the construction, a means of transmitting to it the action of the first mover, by fulfilling the following conditions; viz."

"1. That it may be possible at pleasure, and with great speed and facility, to vary the resistance (against which the effort of the first mover must continually make an equilibrium) in limits of any required extent."

"2. That the resistance, being once regulated, shall be rigorously constant until the moment when it is thought proper to increase or diminish the same."

"3. That in the most sudden variations of which the effort of the first mover may be capable, the variation in velocity of the machine shall never undergo a solution of continuity."

Mr. Prony applies this solution of this problem to the dynamic effect of wind; but it will be easy to make the same general, when other first movers are used. *Fig. 10 (Plate XVI. Mechanics)* represents the plan, and *fig. 11* the elevation of the machine. *OO* is the vertical arbor to which windmill-fails are adapted; *eeee* is an assemblage of carpentry, of which one of the radii, *Oe*, bears a curved piece, *bd*, of iron or steel: vertical axes of rotation *aaa*, being placed round the axis *OO*; they also divide the circumference in which they are found, into equal parts. Each of these axes carries a curve *af*, of iron, steel, or copper; so situated, that when the wind acts upon the fails, the curve *bd* presses against one of the curves *af*: and causes the vertical axis to which this last curve is affixed, to make a portion of a revolution. The curves *bd*, and *af*, must be so disposed, that when *bd* ceases to press on one of the curves *af*, it shall at the same instant begin to act upon the following curve: the number of axes which are provided with these curves, must be determined by the particular circumstances of each case, and it is also practicable to substitute, instead of *bd*, a portion of a toothed wheel having its centre in the axis *OO*, and to place portions of pinions instead of the curves *af*; but the dispositions represented in the figure are preferable. Each of the axes *aaaa* (which are all fitted up alike, though, for the sake of clearness, only one of them has its apparatus represented in the drawing), carries upon it a drum or pulley, *tttr*, on which is wound a cord that passes over a pulley *p*, and serves to support a weight *Q*, by

means of the lever *FG*, upon which this weight may be slid and fastened at different distances from the point of motion *G*. The same axes, *a*, *a*, pass through the pinions *q*, *q*, to which they are not fixed; but these pinions carry clicks or ratchets, which bear against *rr*; so that when the weight *Q* tends to rise, the ratchet gives way, and no other effect is produced on the pinion *qq*, either by the motion of the axis or of the drum *tttr*, excepting that which causes the ascent of the weight *qq*. But the instant that the curve, or tooth *bd*, ceases to bear against one of the curves *af*, after having caused the corresponding weight *Q* to rise, that weight *Q* tends to re-descend, and then the toothed wheel *rr* acts against the ratchet, so that *Q* cannot descend without turning the pinion *qq* along with the drum *tttr*. The pinion *qq* takes in the wheel *ab*, from the motion of which the useful effect of the machine immediately results; so that the effect of the descent of one of the weights *Q* is to solicit the wheel *AB* to motion, or to continue the motion in concurrence with all the other weights *Q*, which descend at the same time. This wheel, *AB*, carries beneath it oblique or bevelled teeth, *GD*, which take in a like wheel, *CE*, and cause the buckets at *S* to rise.

From the preceding description, it is seen that the machine being supposed to start from a state of repose, the wind will at first raise a number of weights, *Q*, sufficient to put the machine into motion, and will continue to raise new weights, whilst those before raised are fallen, so that the motion once impressed will be continued.

Among the numerous advantages of this new mechanism, the following may be remarked:

1. No violent shock can take place in any part of the mechanism. 2. The useful effect being proportioned to the number of weights *Q*, which descend at the same time, this effect will increase in proportion as the wind becomes stronger, and causes the fails to turn with greater velocity. 3. The weights, *Q*, being moveable along the levers *FG*, it will always be very easy to place them in such a manner as to obtain that ratio of the effort of the first mover to the resistance, which will produce the maximum of effect. 4. From this property it results, that advantage may be taken of the weakest breezes of wind, and to obtain a certain product in circumstances under which all other windmills are in a state of absolute inactivity. This advantage is of great importance, particularly with regard to agriculture: the windmills employed for watering lands, are sometimes inactive for several days, and this inconvenience is more particularly felt in times of drought. A machine capable of moving with the slightest breeze, must, therefore, offer the most valuable advantages.

Conductors

CONDUCTORS. In two important branches of natural philosophy, a marked distinction has been observed between the various known bodies of the earth; and upon the peculiar properties of the two different classes of bodies, which are discriminated from each other by the above-mentioned distinction, numerous phenomena, of consequence to the human species, are absolutely depending. The two branches, of natural philosophy, above alluded to, are the science of electricity and the subject of heat. In electricity, if an excited piece of glass, or an electrified conductor, be touched with the extremity of a stick of sealing-wax, which a man holds by its other extremity; or if it be touched with the extremity of a silk string, the electric power will not be dissipated; but if the electrified body be touched with the extremity of a rod of iron or brass, held in a manner similar to the stick of sealing-wax, the electric power will be instantly dissipated; *viz.* it will pass through the metallic rod, and through the person that holds it, &c. Hence it evidently appears, that iron or brass will permit the transition of the electric power through its substance; whereas sealing-wax or silk will not permit it. Therefore, iron, brass, and all those substances through which the electric power can be transmitted, are called *conductors of electricity*; and all those substances, which, like the sealing-wax or the silk, will not permit the passage of the electric power, are called *non-conductors of electricity*.

A similar distinction has been remarked in the subject of heat and cold. Take a small piece of charcoal, make it red hot at one end, and in that state it will be found that a person may hold it with his fingers within about a quarter of an inch of the red hot extremity, without feeling any unpleasant degree of heat; but if an iron rod as thick as

the charcoal be rendered red hot at one end, a person will not be able to hold it within less than four or five inches, at least, of that end; and such is the case with all metallic bodies, as well as with some other substances; which shews that heat will pass through certain bodies much more easily than through others. Hence those bodies which, like the iron rod, will easily transmit the heat through their substance, are called *conductors of heat*; and those which will convey it with great difficulty, are called *non-conductors of heat*. It must be observed, however, that though heat will pass incomparably more easily through certain bodies than through others; yet there are no bodies that are known to be either perfect conductors or perfect non-conductors of heat. And indeed, the like observation, though in a much more limited manner, may be made with respect to the conductors of electricity.

In magnetism also, the name of *conductor of that power* has been given to a single substance, namely, to soft iron; but the peculiar nature of iron in that respect, or rather the passage of the magnetic power, will be explained under the article **MAGNETISM**. We shall now in an orderly manner state the various particulars which have been ascertained with respect to the above-mentioned two classes of bodies; *viz.* first with respect to electricity, and then with respect to heat.

CONDUCTORS of Electricity. In endeavouring to point out the true nature of electrical conductors, it becomes necessary to give a list likewise of the non-conductors of that power, since these two classes of bodies gradually approach each other, in proportion as they are less perfect of their kind, as far as certain substances, which seem to stand in an intermediate state between conductors and non-conductors, so as to participate of both. Glass, sealing-wax, amber,

silk, and several other bodies, which, by means of friction with a dry and clean hand, are capable of being excited, so as to exhibit electrical phenomena, are called *electrics*; and these identical bodies have been found to be non-conductors of electricity; hence *electrics* and *non conductors* mean the very same class of bodies. In the same manner it has been found, that those bodies, which will easily transmit the electric fluid through their substance, cannot be excited in the above-mentioned manner; hence *conductors* and *non-electrics* do also denote the same bodies.

Strictly speaking, as we have already hinted above, there is no substance which may be called a perfect conductor or a perfect non conductor of electricity; the electric power finding some resistance in its passage through the best conductors, and being in some degree capable of passing through the best electrics, at least under certain circumstances. The following lists contain the conductors and the electrics, or, which is the same thing, the non-electrics and the non-conductors. They are disposed in the order of their perfection; that is, the best conductors and the best electrics are placed at the heads of their respective lists; and those which participate of both, meaning those which are partly electrics and partly conductors, will be found towards the end of each list. In this, however, no great accuracy must be expected; first, because a very accurate discrimination is impracticable when substances are expressed under general denominations; and, secondly, because the precise degree of conducting or non-conducting power in most substances cannot be determined on account of their fluctuating nature.

Conductors.

Gold.
Silver.
Copper.
Platina.
Brass.
Iron.
Tin.
Mercury.
Lead.
Semi-metals.

Metallic ores; of which the best are those which contain a greater proportion of metallic parts, and nearest to a reguline state.

Charcoal, either of animal or vegetable substances. The conducting power of charcoal is very equivocal; for some pieces of it will hardly conduct at all, and others will suffer the passage of the electric fluid over their surface only, and not through their substance. The reason of this difference is not quite understood; but it seems owing to the degree of heat that is applied in the process of making them. See Priestley's second volume of Observations on different Kinds of Air, sect. xiv.

Animal fluids.

Acids.

Saline substances.

Hot water.

Cold water.

Salt water.

All other liquids excepting oils.

Red-hot glass.

Melted resin.

Flame, or the effluvia of flaming bodies.

Ice and snow; but not below a certain temperature; for Mr. Achard, at Berlin, in January 1776, observed that

frozen water, or ice, at the temperature of 28° below 0° of Reaumur's scale (equal to —13 of Fahrenheit's) was become an electric. He tried his experiments in the open air, where he found that a rod of ice two feet in length, and two inches thick, was a very imperfect conductor at the temperature of 6° below 0° of Reaumur's thermometer, and that it would not conduct in the least at 20° below 0°. By whirling a spheroid of ice in a proper machine, he even electrified the prime conductor, so as to attract, repel, give sparks, &c., like any other electric.

Most saline substances, of which the metallic salts are the best.

Earthy and stony substances, of which the hardest are the worst.

Glass filled with boiling water, as mentioned by Kinnesley.

Smoke.

Vapour or steam of boiling water.

All compounds, in which different proportions of the above-mentioned substances enter, are conductors in different degrees.

An imperfect vacuum, or the absence of air produced by the action of an air-pump. But a perfect Torricellian vacuum is not a conductor of electricity. Mr. Walsh, assisted by Mr. De Luc, having made a double barometer, in which the mercury had been accurately boiled, so as to expel all the air from the tube, found that the vacuum in the arched part of this double barometer was not a conductor of electricity, nor any electric light could be seen in it. (Priestley's Experiments and Observations on Elastic Fluids, vol. i.) This remarkable discovery was afterwards confirmed by the experiments of Mr. Morgan. (Phil. Trans. vol. lxxv.)

Electrics.

Glass, and all vitrifications, even those of metals.

All gems, of which the most transparent are generally the best.

All resins and resinous compounds.

Amber.

Sulphur.

Baked wood, if not suffered to imbibe moisture.

All bituminous substances.

Wax.

Silk.

Cotton.

All dry and external animal substances, as feathers, wool, hair, &c.

Paper.

White sugar and sugar-candy.

Air, and other gases.

Oils.

Dry and complete metallic oxides.

The ashes of animal and vegetable substances.

All dry vegetable substances.

All hard stones, of which the hardest are the best.

Soft stones when heated, according to Delaval.

Powders not metallic, according to Delaval.

Ice, at the temperature of —13° of Fahrenheit's thermometer, according to Achard.

According to Mr. Walsh's, and Mr. Morgan's experiments, the Torricellian vacuum ought to be placed at the head of the list; but the singular nature of a vacuum, though a non-conductor, will hardly entitle it to the name of an electric. We must, however, refer all farther observations, respecting *electrics*, to the article of that denomination.

the above list having been inserted in this place merely to elucidate the nature of conductors.

Thus far we have stated the number of conductors, and their gradation, with respect to common electricity; but that lately discovered branch of this science, which is at present assiduously cultivated under the title of Galvanism, has pointed out a peculiar arrangement of conductors with respect to the order of their capability of conducting that power which affects the limbs of a prepared animal, and of conveying the power of a galvanic, or rather a Voltaic, battery. See the article GALVANISM. Concerning the former of these powers, we transcribe a list, followed by a few remarks, from Cavallo's *Treatise on Electricity*, 4th ed. vol. iii. p. 20; and with respect to the latter, we subjoin an abridged extract from a paper of Erman, in the *Annales de Chimie*, Feb. 1807.

Conductors of Animal Electricity, according to Dr. Lind's and Mr. Cavallo's experiments, which however are arranged with diffidence by the latter, considering the difficulty of making the arrangement, and that, in this branch of electricity, the metals do not seem to act merely as conductors—the list begins with the best.

“ Malleable platina.

Silver.

Gold.

Quicksilver.

Copper.

Brass.

Tin.

Lead.

Iron.

The human body.

Salt water.

Fresh water.”

“ The metallic ores are not so good conductors as the purified metals themselves, and their conducting power is various according to the nature of the ores, but even the metallic salts are tolerably good conductors.

“ It is very remarkable, that the flame of tallow candle, which is a good conductor of common electricity, will not conduct the animal electricity, when placed in a short interruption made in the circuit of communication. Charcoal, placed in the same situation as the flame of the candle, was also found to be a non-conductor, except when it was actually burning, in which state it conducted tolerably well; but Mr. Volta says that he has found some pieces of charcoal that acted as well as the metals. Dr. Valli observed, that human bodies are not all equally good conductors. Out of four persons in a company, he found that when two of them formed the circuit of communication between the nerve and the muscles of a frog, the motions took place very readily. When a third person formed the circuit, the motions were very weak; but that when the fourth person formed the communication no motion took place. This experiment, he adds, was often repeated with the same success. The effect, however, may be owing to the different dryness of the skin. Vitriolic acid, and what is very remarkable, alcohol, appear to conduct this property rather better than water.

“ The arteries and the veins are not so good conductors as the nerves; for when a blood-vessel forms part of the circuit of communication, the contractions will take place only when nervous ramifications are adhering to it, and if these be carefully separated, the motion will not take place. The same thing may be said of the tendons, the bones, and the membranes: for when either of those parts

is separated from the body, and is introduced in the circle of communication between the muscles and nerves of a prepared frog, no motion will ensue, excepting, indeed, when those parts are full of moisture, and are in immediate contact with the nerve of a prepared frog. Dry nerves are not conductors of animal electricity. Dr. Valli found that the internal substance of a nerve conducts much better than its external, or coat.”

Silver and zinc, professor Aldini says, will produce contractions in the muscles of a frog, many hours after it has become insensible to the action of either of them, separately used.

Mr. Erman, in his paper on two new classes of galvanic conductors, says that the bodies which may be applied to the poles of a galvanic pile are, I. *Non conductors*. II. *Conductors*. The conductors are either *perfect* or *imperfect*; and the imperfect conductors are so, either with respect to both poles, or with respect to one of the poles of a galvanic battery.

I. The *perfect non conductors* prevent the communication of the power of both poles effectually; and such are glass, resins, ice, and the vapour of water, sulphur and its flame, amber, but not its flame.

II. The *perfect conductors*, which discharge both poles completely, are the metals, and all in the same degree.

The *imperfect conductors of both poles*. These, though capable of forming the galvanic circuit, exhibit in their extent effects of two different kinds. Fluid water and bodies impregnated with water are of this nature.

The *imperfect conductors of the positive pole only*. These are incapable of forming the galvanic circuit; for when interposed between the two poles of the pile, they insulate the negative power and conduct the positive; whence it follows, that the negative becomes charged, whereas the positive is conducted. The flame of hydrogen gas, and the flame of the hydrocarbonated bodies, have this property.

Lastly, the *imperfect conductors of the negative pole only* insulate the power of the positive, and conduct the power of the negative pole. Of this sort are the flame of phosphorus and of alkaline soaps.

There now remain two other particulars, which demand our examination with respect to the conductors of electricity. These are the method of ascertaining their peculiar degrees of conducting power, and their uses. The simplest method of determining whether any given body be a conductor or not, is to affix an electrometer to the prime conductor of an electrical machine, and when the machine is in action, and of course the electrometer is diverging, to touch the prime conductor with one extremity of the given body, which the operator holds in his hand by the other extremity; for if, in so doing, the electrometer collapses, the body in question is a conductor; but if the electrometer continues to diverge, that body is a non-conductor. Its degree of conducting power may also be, in great measure, estimated from the quickness with which the electrometer loses its divergency. In the performance of this experiment, the operator should take care that the electric fluid does not run over the surface of the body under trial to the hand that holds it, which generally takes place when the machine acts powerfully, and the body in question is not much extended. In this case, it becomes proper to stop the revolution of the glass globe or cylinder, when the body is to be put in contact with the prime conductor. But if the body be very small, it will be sufficient to use a simple electrometer only, which may be easily caused to diverge by means of an excited stick of sealing-wax, and may then be touched with the body in question. Yet all this is not

sufficient to discriminate the peculiar powers of substances that are of the same class, such as the various metallic substances, the different stones, &c. And for this purpose various other means may be adopted, according to the nature of the bodies under examination. The best way of determining the peculiar conducting powers of metallic substances, is to have wires of the different metals drawn through the same hole, so as to be precisely of the same diameter, and then melt them by the discharge of a battery; viz. take a wire, of about one-fiftieth of an inch in diameter, and connect it with the outside of a battery, containing at least thirty square feet of coated surface, and connect the other extremity of the wire with one branch of the discharging rod. Then, when the battery is charged, touch the wires which proceed from the inside of it with the other branch of the discharging rod, which will force the explosion to pass through the wire that has been interposed between the battery and the discharging rod, generally melting a greater or a smaller part of it, according to the nature of the metal. Thus by repeating the experiment successively with wires of the same length and diameter, but of different metallic substances; charging the battery constantly to the same height, which may be easily accomplished by means of a quadrant electrometer; and measuring the length of each wire that has been melted by the explosion; their various conducting powers may be ascertained; observing that the worst conductors are more easily melted, and *vice versa*. Mr. Henley found that the same charge melted 4 inches of gold wire, 6 of brass, 8 of silvered copper, 10 of silver, and rather more than 10 of iron. In melting wires of a considerable length, as for instance two or three feet, it often happens that the force of the explosion barely renders it red hot, without actually melting it. In this case, it is curious to observe that the redness appears first on that extremity of the wire which communicates with the positive side of the battery, and thence proceeds towards the other end of the wire, which shews an ocular proof of the theory of a single electric fluid; the wire, however, is not rendered red hot at one extremity before the other, in consequence of the progressive motion of the electric fluid through it, but because that fluid loses some of its impetus in going through the wire, so that the wire suffers the greatest effect of the shock on that end which the electric fluid enters; in consequence of which, that same end will be rendered red hot much sooner, and in a greater degree, than those parts which are more remote from it.

When the conducting powers of different fluids are to be ascertained, the best method of performing the experiment is to fill very narrow glass tubes, such as are used for spirit thermometers, with the fluids in question, introducing a pin at each end of the tubes; and to present them successively to the prime conductor, after the manner already described. For other kinds of bodies other methods may be adopted for ascertaining their conducting powers. These, however, need not be particularly described; first, because they may be easily derived from those that have been described above; and, secondly, because they must be varied according to the nature of the bodies in question. After all, it must be acknowledged, that the metals excepted, no very great degree of accuracy can be expected with other substances; since the fluctuation of their conducting powers arises from a variety of slight, and almost imperceptible differences, such as the difference of temperature, of moisture, of admixture with other substances, &c. Thus, glass itself becomes a conductor, when heated to a certain degree; and the very same body will conduct more or less readily, even by being placed nearer to or farther from certain other bodies.

In considering the conducting power of natural bodies, one may naturally ask, whence does that property arise; or how is it, that certain bodies will, whilst others will not, conduct the electric power? The present state of knowledge, however, does not afford a satisfactory answer to this question. Various suppositions have been offered by the late Dr. Priestley and others; but as they are insufficient for the explanation of the phenomena, we shall not attempt to state them in this place.

The uses of conductors are remarkable and extensive, though they are not yet fully ascertained to the entire satisfaction of the speculative philosopher. In the first place, the science of electricity, or the existence of the electric power, would be absolutely unknown, were it not for the difference of conducting and non-conducting bodies; for otherwise the electric fluid which is manifested to us, and operates merely by its passage from one body to another, could neither be confined nor accumulated in any place; in consequence of which, its uniform dispersion throughout the universe would remain inactive and unperceived. But the movements of conducting and non-conducting bodies in the world, their contact, or even their approach without any actual contact, condenses the electric fluid in one place, and rarefies it in another; and this takes place between the clouds and the earth, &c. By the change of their states of existence, some bodies absorb from other bodies; and others deposit upon other bodies considerable quantities of electric fluid. Thus, a perpetual and ample circulation of that fluid is continually kept up amongst all the substances of the teraqueous globe, whence thunder and lightning, vaporization, and probably several other important operations of nature, are derived. In order to understand the action of conductors when opposed to each other, see the nature of electric atmospheres under the article ELECTRICITY.

The greatest advantage which mankind have derived from the knowledge of the present subject, is the adoption of a conductor for the preservation of buildings and vessels against the dire effects of lightning. The identity of electricity and lightning proved by Dr. Franklin, and his subsequent introduction of conductors for preserving buildings, form two of the grandest discoveries of the last century. It was proposed by the above-mentioned philosopher to raise a metallic conductor some feet above the highest part of the building, to continue the same down along the outside of the wall, and below it, deep into the earth, or, which is preferable, to connect it with some well or drain. By these means the house would have little to apprehend from a stroke of lightning; for, since an electrified body is well known to strike the nearest and best conductors that may happen to be in its way, it is evident that the conductor situated in the above-mentioned manner, being of metal, and higher than any part of the building, would naturally be struck by the lightning in preference to any other part, and would conduct it to the ground, without any damage to the building.

This reasonable proposal was no sooner offered by the sagacious Franklin, than it was adopted in America, in Europe, and elsewhere. Numerous facts soon proved the usefulness of such conductors, and extended its adoption by shewing that several houses, which before had been repeatedly struck by the lightning, escaped unhurt after the application of the conductor; that, in many places, the conductors of houses were actually struck by the lightning, which melted them about their extremities, yet the houses themselves received no injury; and so forth.

Though the conductors were instantly adopted, yet their

most useful form, especially with respect to their upper termination, has been much controverted; and it is but lately that the true state of the question has been elucidated. The question was, whether the conductors should terminate in a point, according to Dr. Franklin's original proposal, or in a ball. Mr. B. Wilson exhibited some experiments, in which a point was struck at a greater distance than a ball; whence he concluded, that as the point would attract the lightning from a greater distance, a blunt termination ought to be preferred, since, in certain cases, it would avoid a stroke of lightning, which the pointed termination would not. (Phil. Transf. for 1778). Mr. Nairne, on the other hand, shewed some experiments, in which a ball was struck in preference to a point. And this indeed is confirmed by a great variety of other experiments. In short, a pointed conductor will draw the electric fluid from an incomparably greater distance than a blunt one; but it will draw that fluid gradually, in a stream, or silent manner; whereas the blunt termination will receive it in a full spark, or at once; hence a pointed conductor will tend to diminish the quantity of electricity in a cloud, previous to its coming too near, and thus it may protect a greater extent of building than a conductor with a blunt termination, since the object of fixing a conductor to a house is to protect the house from the effects of lightning, and not the conductor from transmitting the matter of the lightning.

Upon the whole, considering the immense quantity of electricity in a thunder cloud, and the little difference between the action of a blunt or a sharp conductor with respect to that quantity, the difference of those terminations seems to be of less consequence than it was apprehended in the fervour of the dispute. After all the experiments and the discussions made for the purpose, "A conductor," Mr. Cavallo observes, "to guard a building, as it is now commonly used in consequence of several considerations and experiments, should consist of one iron rod, (copper would do much better, it being a more perfect conductor of electricity, and at the same time not being subject to contract rust so soon as iron), about three quarters of an inch thick, fastened to the wall of the building, not by iron cramps, but by wooden ones. If the conductor were quite detached from the building, and supported by wooden posts at the distance of one or two feet from the wall, it would be much better for common edifices; but it is more particularly advisable for powder-magazines, powder-mills, and all such buildings as contain combustibles ready to take fire. The upper end of the conductor should be terminated in a pyramidal form, with the edges, as well as the point very sharp; and if the conductor be of iron, it should be gilt or painted for the length of one or two feet. This sharp end should be elevated above the highest part of the building, (as above a stack of chimnies, to which it may be fastened), at least five or six feet. The lower end of the conductor should be driven five or six feet into the ground, and in a direction leading from the foundations; or it would be better to connect it with the nearest piece of water, if any be at hand. If this conductor, on account of the difficulty of adapting it to the form of the building, cannot conveniently be made of one rod, then care should be taken, that where the pieces meet they be made to come in as perfect a contact with one another as possible; for the electricity finds considerable obstruction where the conductor is interrupted. For an edifice of a moderate size, one conductor, in the manner already described, is perhaps sufficient; but, in order to secure a large building from sustaining any damage by lightning, there should be two, three, or more conductors, in proportion to the extent of the building.

"In ships a chain has often been used for this purpose,

which, on account of its pliability, has been found very convenient, and easy to be managed among the rigging of the vessel; but as the electricity finds a great obstruction in going through the several links, for which reason chains have been actually broken by the lightning, so their use has now been almost entirely laid aside; and in their stead, copper wires, a little thicker than a goose-quill, have been substituted, and have been found to answer very well. One of those wires should be elevated two or three feet above the highest mast in the vessel; this should be continued down the mast, as far as the deck, where, by berding, it should be adapted to the surface of those parts, over which it may most conveniently be placed, and, by continuing it down the side of the vessel, it should be always made to communicate with the water of the sea."

Another precaution must be added to the above directions, which is, that a communication should be made between the conductor, and all other pretty large pieces of metal in the building, such as leaden spouts, large iron clamps, &c.; for otherwise a lateral explosion may take place between those detached pieces of metal, at the time that the lightning is conveyed by the conductor, and thence the building may receive some damage, though not in a very great degree, unless indeed in case of powder mills and powder-magazines. See LATERAL EXPLOSION.

It is owing to this circumstance, that some buildings furnished with a conductor or two, are said to have been struck and to have been damaged by a stroke of lightning. See Phil. Transf. vol. lxxii.

The size of the conductor, as recommended in the preceding paragraphs, has by some been thought too small for the purpose; and an instance is recorded of a conductor of iron, four inches wide, and half an inch thick, which is said to have been made red hot by a stroke of lightning. But with respect to this remark, we shall briefly observe, that should any person think that the conductor, as directed above, is not large enough, the enlargement of its size is attended with no other inconvenience than an increase of expence. However, though a conductor be made red hot, and even melted by a stroke of lightning, yet it will effectually convey that stroke of lightning to the ground without any material injury to the building, as has been sufficiently proved by experiments with artificial electricity, as well as with cases of conductors partly melted by the lightning.

CONDUCTORS of heat. When a congeries of bodies remains long in a given degree of temperature, these bodies will all acquire the same apparent degree of heat; that is, the thermometer placed in contact with any of them, will rise to the same degree; and in this case of equilibrium there is no reason to believe that any heat, or of caloric, passes from one body to another; but if a body, at a certain temperature, be placed amongst bodies of a different temperature, the caloric will, in this case, be communicated from the former to the latter, or *vice versa*; according as the temperature of the former is higher or lower than that of the latter. This communication or passage of heat from one body to another, is made either by *contact* or by *radiation*.—By *contact*, when the bodies, which are contiguous to the hotter one, are progressively heated; viz. the nearest first, and then those which are farther off, without any interruption; as when a red-hot piece of iron is placed amongst other pieces of colder iron, the heat is gradually communicated from the red hot one to the others.—By *radiation*, when the heat from a hot body passes through a vacuum, or through transparent bodies, which are not heated by it, yet it elevates the temperature of bodies placed at some distance. Thus, the solar heat radiates freely through

air, glass, water, &c., and heats opaque bodies without sensibly affecting the transparent bodies through which it passes. Thus also, a thermometer suspended under the exhausted receiver of an air-pump, or in the Torricellian vacuum, continues to vary its temperature with that of the surrounding bodies.

In the communication of heat from one body to another, when a third body is interposed, it has been observed that the transition of heat is much quicker when certain bodies are interposed, than when other bodies are placed between; but there are no bodies known which prevent that transition effectually; hence the bodies of the universe are distinguished into more or less perfect conductors of heat, but they afford no instance of a perfect non-conductor.

The transmission of heat from a solid at a higher degree of temperature, to another at a lower one, in a given time, is nearly proportional to the difference of their temperatures. But the velocity with which heat is propagated through the substance of different bodies, varies considerably according to the nature of those bodies. In general, metallic bodies are the best conductors of heat; stones, or hard earthy bodies come next; then the vitreous substances, and the resinous. Dry animal parts, excepting bones, and especially dry and light vegetable bodies, are bad conductors of heat. The conducting power of liquids is of a particular nature, which will be mentioned presently. But the different bodies of the same class differ considerably in conducting power. Thus the metals possess it in different degrees, and their proportional powers were thus estimated by Dr. Ingenhousz. He procured equal cylinders of several metallic substances, and having coated them with wax, he plunged their extremities in hot water, and judged of the conducting power of each, by the length of the wax-coating that was melted. The result of these experiments is expressed in the following list, which commences with the best conductors. Journ. de Phys. 1789, p. 68.

Silver.	} nearly equal.	
Gold.		
Copper.		
Tin.		
Platina.	} much inferior to the others.	
Iron.		
Steel.		
Lead.		

In the same paper, the proportional conducting powers of three fluids are stated in the following manner:

	<i>Equal bulks.</i>	<i>Equal weights.</i>
Water	- 1.	1.
Mercury	- 2.	4.8
Lined oil	- 1.111	1.085

The conducting power of the same body does not remain invariably the same in all circumstances; but it differs, according as the body changes its state of existence, so that the conducting power of a body in a solid state is different from that of the same body in a fluid state. And at the time of changing its state of existence, the conducting power in most cases ceases altogether. Thus, at the temperature of 60°, sulphur is a conductor; but when heated to 212°, at which point it melts and becomes volatile, it is no longer a conductor. Thus also, ice conducts at the temperature of 20°, or at any other temperature below the freezing point, which is 32°; but at that point it ceases to be a conductor, because the heat which may be communicated to it is absorbed as an ingredient necessary to its fluid state, which it assumes at, or little above, that point.

Rarefaction or condensation alters the conducting powers of several bodies. Yet the rarefaction of air is by no means accompanied with a proportionate diminution of its conducting power.

Professor Pictet supposes that heat ascends within solid bodies more readily than it descends; viz. that in communicating heat to a solid body by the lateral application of a hotter body, the upper parts of the former are heated sooner than the lower. This effect, however, may with propriety be attributed to the ascending current of heated air which rises along the surface of the body, and causes colder air to approach the lower part of the body; hence the heat is continually carried upwards.

The conducting power of a body changes likewise, in consequence of an alteration of the surface; so that polish and figure are likewise concerned in the reception as well as in the propagation of heat. These particulars, however, together with the reflection and refraction of heat, from the surface or through the substance of bodies, will, with more propriety, be explained under the article HEAT.

Fluids are, upon the whole, very imperfect conductors of heat, and Count Rumford was led, by his experiments, to conclude that heat is not at all propagated through them by contact, as it is in solids. (See Rumford's paper on the Conducting Property of Fluid, &c. Phil. Trans. 1805.). Whatever permits or promotes the motion of the particles of a fluid, contributes to the propagation of heat;—whatever obstructs that motion, retards the propagation of heat through them. The particles of air which come in contact with an heated body, being thereby heated and rarefied, become specifically lighter than the surrounding air, and of course ascend; other air then comes in contact with the heated body, and this also being heated is caused to ascend, and so forth. Thus is heat conveyed from the original hot body, by the air, to a distance from it; but if that motion of the air be obstructed, as by the interposition of partitions of paper, wool, cotton, furs, and the like, then the communication of heat is prevented more or less effectually. It is principally on this account, that furs, feathers, eider down, cotton, and other similar things, form warm coverings; viz. because, by preventing in great measure the motion of the air between their filaments, they prevent at the same time the dissipation of heat.

The like observations are applicable to water, and perhaps to all other fluids. When a vessel full of water is set upon the fire, the particles of water that are close to the bottom of the vessel are first heated and rarefied; in consequence of which they ascend, and other colder particles take their place, which, being heated, likewise ascend, and so on. If the fire be applied to the upper part of the water, the fluid will not be heated, or at most it will in a very slight degree. Count Rumford (see his 7th Essay) confined a piece of ice at the bottom of a pretty tall glass vessel full of water nearly boiling, and noted the time it took up to melt the ice. The experiment then was repeated with this difference, viz. that a similar piece of ice was placed on the surface of the hot water, instead of the bottom. It was found that the ice melted more than eight times quicker in this last situation than in the former. The result of this remarkable experiment is explained in the following manner. When the ice swims on the surface of the hot water, the particles of the latter, that are contiguous to the ice, being cooled by it, descend, and other hot particles of water take their place, which deposit their heat upon the ice, and, being thereby rendered specifically heavier than the next particles of water also descend, and so forth. But when the ice is confined a,

the bottom of the vessel, the particles of hot water which come first in contact with it, are cooled, and are rendered specifically heavier, in consequence of which they remain in their place, and no motion will take place within the water; hence the ice is not melted nearly so readily as in the former situation. Now count Rumford contends that it is by means of the above-mentioned motion only that heat is propagated through fluids, and not otherwise. This conclusion was no sooner published to the scientific world, than it was opposed in an able manner by very skilful philosophers. See Dalton's paper. *Nich. Journ.* vol. iv. p. 75. Traill's paper, *ibid.* for 1805, p. 133; and Murray's paper, *ibid.* vol. i. From these papers we shall make the following abridged extracts, which seem necessary for the elucidation of the subject; and in the first place we shall state Mr. Murray's experiments.

Into a glass cylindrical vessel water was poured, till it covered the bulb of a thermometer; its temperature was 46° , which was likewise the temperature of the air of the room. One ounce of olive oil, heated to 140° , was poured on a small piece of cord, suspended on the surface of the water, and the cord was slowly withdrawn. Any motion of the water was thus avoided. In the course of a minute the thermometer began to rise slowly; in five minutes from the commencement of the experiment, it had risen 4° , in ten minutes $6\frac{1}{2}^{\circ}$, in fifteen minutes 8° . It then became stationary, and continued so for seven minutes, before it began to fall. Its descent was slow. This experiment was repeated with a hot metallic ball (instead of oil) immersed in the water above the thermometer, and it was attended with a similar effect.

From these results the conclusion might seem just, that the fluid must possess a conducting power. Yet this is rendered doubtful by the circumstance, that in all experiments of this kind, a quantity of caloric must be conveyed by the sides of the vessel. In order to avoid this source of error, Mr. Murray employed a vessel of ice. But water could not be used in this case, because that fluid expands from 40° to 32° ; therefore oil and mercury were used.

A quantity of almond oil was poured into the ice vessel, so as to cover the bulb of the thermometer a quarter of an inch. A small cylindrical iron cup, two inches in diameter, and having a flat bottom, capable of holding two ounces by measure, was suspended so as merely to touch the surface of the oil, and was filled with boiling water. At the beginning of the experiment, the thermometer stood at 32° . In a minute and a half it had risen to $32\frac{3}{4}^{\circ}$, in three minutes to $34\frac{1}{2}^{\circ}$, in five minutes to $36\frac{1}{4}^{\circ}$, in seven minutes to $37\frac{1}{2}^{\circ}$. At this point it became stationary, having risen $5\frac{1}{2}^{\circ}$ in seven minutes. The temperature of the water in the cup had in this time fallen to 96° . The thermometer, after remaining stationary at $37\frac{1}{2}^{\circ}$ for six minutes, began to fall, and it continued to descend at the rate nearly of a degree in a minute and a half, till it returned to 32° . The experiment was repeated with this variation, *viz.* that the thermometer was placed lower, so that half an inch of oil stood over its bulb. It was also repeated with mercury instead of oil. But in both cases the results were similar to that of the first experiment.

"This rise," Mr. Murray says, "it appears to me impossible to ascribe to any other cause than to a power in the fluid to conduct caloric. Thus it is evident, that the sides of the vessel could not convey to the fluid in contact with the bulb of the thermometer any part of the caloric it received. Ice, in common with any other solid, may, at temperatures below its melting point, conduct caloric; but as it cannot possibly exist with a temperature above 32° , it cannot communicate any temperature above that to a fluid in contact with it, and consequently it could not contribute in the

above experiment to raise the thermometer above that temperature. Caloric does not radiate through transparent fluids, and it cannot even be supposed capable of passing by radiation through an opaque fluid as mercury.

If it be proved that oil and mercury are capable of conducting caloric, it will be admitted as sufficiently probable, that other fluids may have a similar power. Of these two, mercury, it is probable from these experiments, is the best conductor, as the rise of the thermometer took place in it much more rapidly than in the oil."

Dr. Traill's experiments for ascertaining the conducting powers of divers fluids, were performed in the following manner.

A cylindrical vessel was turned out of wood, having its sides half an inch thick, its height four inches and its diameter two. It has a moveable wooden top or cover, perforated with a hole in its centre, a little more than an inch in diameter, into which an iron cylinder, of one inch in diameter, could be easily introduced. This cylinder is supported by a slight flanch, or shoulder-piece, and can be taken up by means of a string attached to its top. When the iron bar is in its place, its flat lower extremity is half an inch distant from the bulb of a delicate mercurial thermometer, which is fixed by wax in a hole perforating the cylinder near its bottom. This thermometer is bent to a right angle, so that its bulb and part of its stem lie in the axis of the wooden cylinder. This shape was preferred, because the stem could be little affected by the caloric transmitted by the sides of the vessel, till after the bulb was acted on by the caloric of the iron bar.

A variety of experiments was performed with this apparatus in the following manner: The temperature of the room being steadily 67° , Fahrenheit. therm.; during the trials, a kettle of water was kept boiling over the fire. Its temperature was between 211° and 212° , and in this the cylinder of iron was suffered to remain, at each experiment, for fifteen minutes. The liquid to be examined, and all the apparatus (but the iron bar) were at each experiment ascertained to be at 67° . The liquid was poured into the wooden vessel, till it could rise $\frac{1}{8}$ of an inch on the side of the iron cylinder when in its place. The wooden top was put on, and the iron was drawn out of the kettle of boiling water by means of the attached string, and instantly let down through the hole of the cover. The time the thermometer took to rise through 3° (*viz.* from 67° to 70°) was accurately marked by means of a stop-watch, and the results of the experiments on several fluids, are exhibited in the following table.

Liquids.	Minutes.	Seconds.
Water	7	5
Cow-milk	8	25
Proof spirit	8 nearly	
Alcohol. Lond. Pharmac.	10	15
Transparent olive oil	9	50
Mercury	9	15
Solution of sulphate of iron. Salt 1. Water 5.	8	
Saturated solution of sulphate of alumine	9	40
Saturated solution of sulphate of soda	6	30
Aqua potass. pura. London Pharm.	8	15
Saturated solution of sulphate of soda, but the liquid not touching the iron cylinder, by $\frac{1}{8}$ of an inch, or nearly so	19	20

"If I am not deceived," says Dr. Traill, "we may conclude, from what I have above adduced, that liquids, as well as solids, are conductors of caloric; that the transmission of it through them follows a particular law depending on the properties of the particular liquid; but which is not in the exact ratio of any of their mechanical properties, though nearer that of their density, than any other."

A circumstance, deserving the attention of the speculative philosopher, respecting the conductors of electricity and of heat, has been observed; viz. that most of those bodies which are good conductors of the one, are likewise good conductors of the other. This law, however, is not without exceptions. Thus, metallic bodies are good conductors of both; but charcoal is a good conductor of electricity, though a very bad conductor of heat.

The last particular, which we shall briefly notice, with

respect to the conductors of heat, is their use. This, on the least examination, will be found to be very extensive. Nature and art avail themselves of these peculiar properties of bodies, and without them both animal and vegetable life could not subsist. The atmospherical fluid which envelops the earth, is a very bad conductor of heat, undoubtedly created for the purpose of not dissipating the heat of the earth and terrestrial bodies. The coverings of animals, such as furs and feathers, being extremely bad conductors, confine the heat on the animal body. The bark and ligneous part of plants, in consequence of their imperfect conducting powers, tend to prevent the freezing of vegetable juices. The industry of man has not omitted to use the worst conductors of heat for coverings, for the defence of his habitations, for the confinement of heat in certain furnaces, &c. In short, numerous and admirable effects are deduced by Providence, and several essential advantages are obtained by art, from a proper application of the various conducting powers of natural bodies.

Congelation

CONGELATION (from the Latin *congelō*), means the transition of a liquid into a solid state, in consequence of the abstraction of heat; thus metals, butter, oils, water, &c. are said to *congeal*, when, from a fluid state, they pass into that of a solid.

Congelation and freezing mean, in fact, the same effect; yet the term congelation is indiscriminately applied to all the above-mentioned transitions; whereas the word freezing is more commonly used for denoting the congelation of water, of vinegar, of brandy, of mercury, and in short of all those substances which, in order to become solid, must be cooled below 32° of Fahrenheit's thermometer. We shall, however, in this work, divide the subject of congelation under the two above-mentioned denominations; stating, under the present article, whatever relates to natural congelation, and under the article FREEZING, whatever relates to the artificial methods of freezing.

Another important process, much connected with congelation, has been improperly separated from it. And this is *crystallization*, or the arrangement of certain substances into regular figures, in their transitions from the fluid into the solid state; but water and several other bodies likewise crystallize in congealing, which shews that the two processes can hardly be separated; and this is rendered still more evident by a due consideration of other phenomena that accompany both processes. Allowing therefore that crystallization and congelation are essentially of the same class, a slight discrimination may be formed by applying the term crystallization to the formation of those regular forms or crystals,

which are of a compound nature, and which, when once formed, generally require a much greater degree of heat for their liquefaction, than that in which they were formed.

By far the greater number of liquids we are acquainted with, have been found capable of congelation in a proper temperature; and on the other hand most of those solids which are such in the usual temperature of the atmosphere may be rendered fluid by the application of certain appropriate degrees of heat; hence we are led by analogy to suppose, that every fluid might be congealed, if it were possible to cool it sufficiently; or that fluidity is the effect or consequence of heat. Every particular kind of substance requires a different degree of temperature for its congelation; hence it appears why certain substances remain always fluid, whilst others remain always solid, in the ordinary temperature of the atmosphere, and why certain other substances are sometimes fluid, and at other times solid, according to the vicissitudes of the weather, the difference of seasons, and the variety of climates.

Heat, or sensible caloric, continually tends to pass from those bodies which have more of it than their proper share, to those contiguous bodies which have less of it than their proper share; hence, when a body is placed amongst other bodies of a lower temperature, its heat gradually passes to those other bodies, until the whole acquires the same temperature; and this transition proceeds regularly, excepting, however, when the body is in the act of assuming the solid state; for at that moment a sudden extrication of heat is observable. Place a thermometer in a glass full of water,

Vinegar congeals at about	- - -	28° F.
Hu nan blood congeals at	- - -	25.
Strong wines congeal at about	- - -	20.
A mixture of one part of alcohol and three of water congeals at	- - -	7.
A mixture of alcohol and water, in equal parts, congeals at	- - -	minus 7.
A mixture of two parts of alcohol and one of water, congeals at	- - -	minus 11.
Mercury congeals at	- - -	minus 39.

Mercury exposed to cold, and at about the point of congelation, contracts its bulk irregularly. This substance may be cooled some degrees below its freezing point, before it assumes the solid form; but as soon as it begins to harden, the thermometer rises to its freezing point, which, from a variety of experiments made by Mr. Huthchins at Hudson's Bay, appeared upon his thermometer to be -40° . "But (Mr. Cavendish observes in the Phil. Trans. vol. lxxiii. p. 321.) as it appeared from the examination of his thermometer, after it came home, that -40° thereon answers to $-38\frac{1}{2}$ on a thermometer adjusted in the manner recommended by the committee of the Royal Society; it follows, that all the experiments agree in shewing that the true point at which quicksilver freezes, is $-38\frac{1}{2}$, or in whole numbers 39° below nothing." In becoming solid, mercury sometimes shoots into crystals or longitudinal filaments like pins. The first observations concerning the natural congelation of mercury were made by Mr. Gmelin about the year 1735, at Yeniseick in lat. $58\frac{1}{2}^{\circ}$ north, at Yakutsk in lat. 62° north, at Rivengo, lat. $57\frac{1}{2}^{\circ}$ north, and elsewhere. (See the Petersburg Commentaries for the years 1756 and 1765). Professor J. A. Braun, of Petersburg, in the year 1759, first accomplished the congelation of mercury by art, viz. by means of snow and aqua fortis. But with respect to the artificial methods of congelating mercury, and their history, see the article FREEZING.

Nitric acid is said to congeal at - - - minus 66.

With respect to the congelation of the sulphuric, or vitriolic acid, the greatest number of experiments seems to have been made by Mr. Keir, and from those experiments he infers: "1. That the vitriolic acid has a point of easiest freezing, and that this is when its specific gravity is to that of water as 1780 to 1000. 2. That the greater or less disposition to congelation does not depend on any other circumstance than the strength of the acid. 3. That the freezing and thawing degree of the most congealable acid is about 45° of Fahrenheit's scale. It is, however, to be observed, that this degree is inferred from the temperature indicated by the thermometers immersed in the freezing and thawing acids; but the congelation of the fluid acid could never be accomplished without exposing it to a greater degree of cold, either by exposing it to the air in frosty weather, or to the cold of melting snow. 4. Like water, this acid possesses the property of retaining its fluidity when cooled several degrees below the freezing point; and of rising suddenly to it when its congelation is promoted by agitation, or by contact even with a warmer thermometer. 5. That, like water and other congealable fluids, the vitriolic acid generates cold by its liquefaction, and heat during its congelation, though the quantity of this heat and cold remains to be determined by future experiments. 6. That the acid, by congelation, when the circumstances for distinct crystallization are favourable, assumes a regular crystalline form, a considerable solidity and hardness, and a density much greater than it possessed in its fluid state."

The heat of the earth, at least on the surface of it, is de-

rived entirely from the sun; for the heat arising from combustion, as about volcanos, or from decomposition of bodies, is trifling and partial. The direct rays of the sun on the same spot of the surface of the earth heat it more or less, according to the time of the year, clearness of the atmosphere, state of the winds, colour and quality of the spot. In Great Britain, during the hottest time of the summer season, the direct rays of the sun seldom raise the mercury in the thermometer so high as 110° . But in other climates, especially within the tropics, the mercury is raised considerably higher by the like exposure. Yet we must not believe the idle stories of the sun's heat melting lead, or setting fire to gun-powder, without the assistance of lenses, speculums, or other artifice.

It is not on account of the sun's being nearer or farther from the earth, that we receive much more heat in the summer than in the winter time; since the difference of those distances is too small to be sensibly felt; but we receive more heat in the summer than in the winter season. 1. Because the sun comes nearer to our zenith in the summer than in the winter time, in which situation its rays pass through a shorter portion of the atmosphere, and of course are less intercepted by it. 2. Because, when the sun is nearer to the zenith, a greater quantity of its rays falls upon a given horizontal part of the surface of the earth, than when that luminary stands lower, and its rays fall more obliquely upon the same spot. 3. Lastly, because the sun remains longer above the horizon during a summer day than a winter one.

The hottest part of the day is not at noon, nor that of the year when the sun passes nearest the zenith of a given country; but the hottest part of the day, when no accidental circumstance intervenes, is some time in the afternoon, and nearer to noon in the winter than in summer. In this country and in summer, the hottest part of the day generally is either precisely at, or a little before, two o'clock. The hottest time of the year in this country generally takes place in July, viz. after the solstice. The reason of this is, that though the rays of the sun give more heat when the sun stands higher, and of course at two o'clock they must give less than at noon; yet the earth, and the air contiguous to it, are hotter at two o'clock, because, besides the heat which they are actually receiving from the sun, they retain a considerable portion of the heat acquired before that time; so that as long as they acquire at any particular time, a greater quantity of heat than they lose of that which they had previously acquired, their temperature must continue to increase. The same thing must be understood with respect to the communication of cold, which, for similar reasons, is greatest some time after midnight, and some time after the shortest days of the year. The earth acquires heat in the day time, and loses it during the night. In the summer season the loss of heat during the night is less than the acquisition of it during the day; therefore that excess of heat is gradually communicated from the surface to the more internal parts of the earth. But when the above-mentioned summer heat has penetrated a certain way, the winter cold begins to counteract it; and when that cold has penetrated a certain way, the next summer heat begins again to counteract it, and so on; hence, below a certain depth there is no alteration of temperature at any time of the year; unless some local combustion or other source of heat should interfere, which, however, seldom occurs. This fixed degree of temperature at a certain depth below the surface of the earth, varies in different countries, and nearly coincides with the mean temperature of the particular country. Thus in London the mean temperature is 50° ; and if a bucket of water be drawn from a pretty deep well, and a thermometer

be instantly placed in it, the temperature of that water, (which is the same as that of the ground surrounding the bottom of the well) will also be found to be 50° . In process of time the mean temperature of a country is liable to some alteration arising from cultivation, clearing of grounds, draining of marshy grounds, &c. See CLIMATE.

With respect to the temperature at different altitudes, it has been found that a thermometer placed close to the ground is sometimes affected by heat or cold, sooner, or in a greater degree, than a thermometer placed 20, or 30, or 60 feet, higher up; and that at other times the latter is affected sooner, or in a greater degree, than the former. In the night time, especially when the air is still, and the sky quite free from clouds, a thermometer close to the ground generally indicates a greater degree of cold than in a higher situation. The true cause of this phenomenon is not fully understood; though it is attributed to evaporation, or according to Mr. Six, to the coolness which the dews or vapours may acquire in their descent.

At great heights above the surface of the earth, either in the free air, or on the summit of high mountains, the cold is much greater, and it increases more suddenly; 1st, because they are much more exposed, and 2dly, because they are more remote from the body of the earth, which, as has been observed above, tends to equalize the temperature, by retaining in the winter time a considerable degree of the heat acquired in the course of the summer. The winds to which mountains are exposed, especially those which, after having blown over the plains below, rise along their sides, have a peculiar refrigerating power, arising from the expansion of the ascending air, which becomes capable of absorbing more heat in proportion as it is more rarefied. See Dr. Darwin's Paper, Phil. Trans. for 1788.

Thus we have briefly stated the natural sources, and the principal causes which check or promote the heat and the cold, that are usually experienced in the world, at different times of the day, of the year, and in different countries; whence alone one may pretty well conceive where and when natural congelation may be expected to take place. Yet it is necessary to subjoin some farther observations, that have been made with respect to natural congelation at different times and different places.

The greater obliquity with which the sun's rays fall upon the northern and southern parts of the earth, than they do upon such parts as are near the equator, undoubtedly produces the variety of the mean temperatures that are observed in different latitudes; the higher latitudes being generally colder than the lower, and *vice versa*. But this gradation is partly counteracted by a variety of local circumstances; and such are the vicinity of large tracts of land or great extent of sea, the face of the country being flat or hilly, the disposition of the hills and mountains, the prevalence of rain and of certain winds, the state of cultivation, &c. The influence of winds in certain latitudes is so very great that a frost or thaw is brought on within a remarkably short time by a change of the wind. The action of winds on the temperature of a country principally depends upon three circumstances, viz. on their bringing a quick succession of new air in contact with the bodies that are exposed to it, on their having passed over the surface of hotter or colder tracts of water or land, and upon their increasing the evaporation. Saussure found that when the wind moves at the rate of forty feet per second, it triples that quantity of evaporation that would take place in calm air; hence it follows that frequently unusual heats or colds come on at unexpected times, and that the higher strata of the atmosphere are often warmer than the lower; for the heat

of the atmosphere is derived not from the immediate action of the sun's rays which pass through it, but from the warmer and more solid bodies with which it has been, or is, in actual contact. In consequence of these various circumstances, it has been observed that the north Pacific Ocean, above latitude 40° , is much colder than the north Atlantic, between the same parallels of latitude. The interior parts of Siberia, east of longitude 100° , are much colder than the parts equally distant from the meridian on the western side. The coast and interior parts of the western regions of America are much colder above the latitude of 40° , than the corresponding tracts of the continent of Europe. Large seas, which are agitated by winds and currents, are thereby so little affected by cold winters or hot summers, as to preserve a temperature nearly uniform in every season, like the internal parts of the earth.

With respect to the mean temperature of places at different altitudes above the level of the sea, but in the same country, or nearly about the same spot with respect to latitude, the heat diminishes nearly one degree of Fahrenheit for every 200 feet of elevation, according to Dr. Black. Other writers find reasons to assert, that the diminution of one degree takes place at every 299 feet of elevation.

From the statement of all the above particulars the reader may form some idea of the time and place when natural congelation may be expected, and he will at the same time be able to perceive that close to the surface of the earth, no great regularity can be expected. On the continent of Europe congelation formerly took place at a lower latitude than it does at present, when natural congelation is seldom observed lower than the latitude of 40° . In America congelation has been observed at a much lower degree; and it is remarkable that great degrees of heat, as well as great degrees of cold, are alternately experienced on the same spots of that continent. In the more northern parts of the world the degrees of cold are very extraordinary. At Torneao, Reaumur's spirit thermometer fell to minus 34° . In Siberia the spirit thermometer has been known to descend as low as minus 121° . Even at the Glasgow observatory in the year 1780, the mercury of the thermometer exposed to the ambient air was found to stand at minus 14° .

The altitude on the sides of mountains, at which constant congelation takes place, seems to be less fluctuating, though not accurately ascertained. This altitude varies with the latitude; but even in the torrid zone perpetual congelation has been observed (according to Bouguer and others) at the altitude of about 15600 feet. This altitude, at which the congelation is constant, or where water ceases to be a fluid, and beyond which visible vapour does not seem to ascend, is called the *upper line of congelation*. The *lower line of congelation* is where it freezes at night only. The upper line of congelation, within the tropics, has been observed at the altitude of 15600. Near the tropics, on the sides of the temperate zones, it lies at the height of about 13428 feet. On the island of Teneriffe, in lat. 28° N, it lies at the altitude of about 10000 feet. In Auvergne, lat. 45° N., the line of congelation is at the altitude of 6740 feet. In latitude between 51° and 54° N. it seems to be at the altitude of about 5800. In latitude 80° north, Lord Mulgrave found the line of congelation at the altitude of about 1200 feet above the level of the sea; whence, if the progression continues uniformly, as general Roy observes, we may conclude that the surface of the earth, at the pole itself, is for ever covered with congelation. Mr. Kirwan, however, places the upper line of congelation considerably higher. See his paper on the variations of the atmosphere, in the 8th vol. of the Trans. of the

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Royal Irish Academy. He reckons the altitude of the line of congelation from 0° to 10° of north latitude, at about 27700 feet; from 10° to 15° at about 26400 feet; from 15° to 20° , at about 25200 feet; from 20° to 25° , at about 24000 feet; from 25° to 30° , at about 22000 feet; from 30° to 35° , at about 20000 feet; from 35° to 40° , at about

17000 feet; from 40° to 45° , at about 15000 feet; from 45° to 50° , at about 12500 feet; and for every one of the other degrees of latitude, at the altitudes which are annexed to them in the following table. These results, however, he deduced by computation from a few ascertained particulars.

Degrees of N. lat.	Altitude of the line of congelation.	Degrees of N. lat.	Altitude of the line of congelation.
51 $^{\circ}$	10124	71 $^{\circ}$	4354
52	8965	72	4295
53	7806	73	4236
54	6647	74	4177
55	5617	75	4119
56	5533	76	4067
57	5439	77	4015
58	5345	78	3963
59	5251	79	3911
60	5148	80	3861
61	5068	81	3815
62	4989	82	3769
63	4910	83	3723
64	4831	84	3677
65	4752	85	3631
66	4684	86	3592
67	4616	87	3553
68	4548	88	3514
69	4480	89	3475
70	4413	90	3432

Cooling

COOLING is the progressive decrease of temperature from a higher to a lower degree. From the highest degree of heat, which human industry has been able to obtain by means of combustion, or by concentrating the solar rays, to the lowest degree of it, which both natural and artificial methods have produced, the scale is very considerable; and different parts of it have obtained diverse denominations, which are derived from the most striking phenomena that take place at particular points of the scale; thus we hear of porcelain heat, white heat, red heat, boiling heat, temperate, freezing, &c. and all these transitions from the first to the last, fall under the denomination of *cooling*; whereas the contrary transition from the lowest to the highest, is called *heating*. In order to preserve perspicuity, and to assign to each of the received denominations, the particulars which belong more immediately to it, we have divided the subject into three articles, under the words *congelation*, *cooling*, and *freezing*. Under the first we have stated the phenomena of natural congelation; the last contains whatever relates to artificial freezing, viz. to the production of cold below 32° of Fahrenheit's scale; and under the present, we shall principally state all the methods and the effects of cooling from the actual temperature of the atmosphere to a lower degree; but not below that of melting ice, viz. 32° , which is commonly called the freezing point.

The temperature of the atmosphere in the hottest climates, has hardly ever been known to exceed 130° , and it is

but seldom that it reaches that most oppressive degree of heat. In the human species, nature has made ample provision, and has furnished them with industry sufficient for counteracting the effects of a very high or a very low temperature; but without any artificial assistance, few are the degrees of heat in which human beings can live with perfect comfort. Making some allowance for the natives of different climates, the whole range temperature may be said to reach from the 60th to the 70th degree of Fahrenheit's scale. Below 60° most persons have no objection to a gentle fire in their apartments; and above 70° they generally complain of heat. Yet when the natural temperature of the atmosphere is above 50° , cooled liquors are generally preferred for drink; but when the temperature is above 70° ; then not only cooled liquors, but cool apartments also, are articles of great luxury; and (it may in great measure be said) of necessity. The languor which is commonly induced by heat, is in great measure relieved by artificial cooling. Patients affected with fevers of the intermittent and putrid kinds, which are so very common and destructive in hot climates, receive great benefit from the use of cooled liquors, and such are plentifully administered to them, whenever they can be obtained. The preservation likewise, of meats, fruit, butter, &c. in warm climates, or in the hot season, is considerably assisted by cooling; and it may be extended to a very remarkable long period by actual freezing.

In order to answer all these purposes, mankind has, from time immemorial, endeavoured to discover and to apply me-

thods of cooling, or of refrigeration. These methods, as far as they are at present known, may be comprised under the following heads; *viz.* 1st, the application of something naturally colder than the actual temperature of the atmosphere; 2dly, ventilation; 3dly, evaporation; and 4thly, the solution of certain saline substances. Sometimes two or three of these means are applied at the same time, to the article which is required to be cooled. In every country of Europe, and especially in the southern part of it, ice is collected during the winter, in proper places, and is used for cooling liquors, &c. in the summer season, or throughout the whole year. And this undoubtedly is the most easy, the most extensive, and the most effectual method of cooling. A little ice taken out of the ice-house, and placed round a bottle of water or wine, in any convenient vessel, soon cools it to the desired degree; and if the effect is to be increased, so as to freeze creams, fruit, &c. by breaking the ice into small pieces, and mixing common salt with it, the desired end will be obtained. The ice-house itself is of very essential use for preserving meat, fish, butter, fruit, &c. which things need only be laid in it, until they are wanted.

When ice cannot be easily procured, well water forms a useful substitute to a certain degree. When the depth of the well is 40 or 50 feet, or upwards, the constant temperature of its water is very nearly equal to the mean temperature of the country, which, of course, is lower than the usual temperature of the summer season in that country; hence, if a pail of water be drawn, and a bottle of wine, or other liquor, be immediately placed in it; a considerable refrigeration may be obtained, and it may be maintained by drawing fresh water at intervals from the well, &c. Thus in London the mean temperature is about 50°, and so is the temperature of pretty deep wells throughout the year. Now in the summer season, the temperature frequently rises above 65°, or 70°; therefore, at those times, by applying fresh drawn well-water, the liquors we drink may be cooled about 15 or 20 degrees, which will render them incomparably more pleasant. When articles of food are required to be kept some time longer than the heat of the weather would allow, they may be placed in a basket at the end of a rope, and may be let down into the well, until they come within a foot or two of the water. For the like purposes, pretty deep pits, caves, or grottos may be used; since their temperature is nearly equal to the mean temperature of the country, and suffers little or no variation between winter and summer.

Ventilation is nothing more than a constant change of air; but if the air which has just passed by a body, and that which succeeds it are all of the same temperature, no cooling will be produced by the ventilation; but the refrigeration will take place, when the body is hotter than the air which passes by it, or when an increase of evaporation ensues. Expose a thermometer to the open air, but shelter it from the wind, and when the thermometer is become stationary, let the wind fall upon it; and it will be found that the quicksilver is not lowered in it. But when a human being, or other animal is exposed to ventilation, the quick transition of air cools it; first, because it continually removes the air which has been heated by the contact of the animal body, the breath, &c.; and secondly, because the evaporation from the body is increased by the ventilation. So that, upon the whole, the use of ventilation, such as is effected by means of fans, bellows, a particular disposition of apartments, and other machines, is to remove heated or vitiated air from the vicinity of human beings, from close habitations, prisons, ships, &c. The ingenious Dr. Hales fixed a machine of this sort in the old Newgate prison, which, being put in action by means of

ails, like a wind-mill, constantly ventilated the inside of that prison; and this machine remained in use until the rebuilding of that prison upon a better plan rendered it superfluous. See VENTILATOR.

Hitherto we have supposed, that the air is colder than the human beings who are exposed to it; but should the contrary be the case, then ventilation will produce a different effect; *viz.* it will heat, instead of cooling, as may be easily conceived by considering what has been said above. And such is the case with the hot winds, which sometimes blow in Arabia, Africa, India, and other places.

One of the most useful and efficacious modes of cooling, especially in those countries where it may be most wanted, is performed by means of evaporation. The principle upon which the cooling power of evaporation depends, is, that whenever a body is expanded, *viz.* its volume is increased, its capacity for containing heat is increased at the same time; hence the expanding body absorbs the heat of the surrounding bodies, which, of course, are cooled by it.—A short experimental illustration of this theory will easily explain the effect we are treating of. Take three common mercurial thermometers; keep one in its natural state; place the second in a bottle of water, and close its aperture; wrap some cotton moistened with water round the bulb of the third; then expose all the three thermometers thus prepared to the ambient air, especially when the wind blows in the summer season; and after a few minutes observe their progress. It will be found that the naked thermometer, and that which stands in the bottle, indicate the same degree of temperature; but the third thermometer, which is wrapped in moistened cotton, will be found to indicate a temperature lower by a few degrees, than the former. The effect in this experiment is produced by the evaporation of the water from the cotton, and not from the water as water; for if that were the case, the thermometer in the bottle of water would likewise be cooled like the one involved in moistened cotton. Evaporation is the conversion of water into steam, or vapour; and the bulk of steam has been found to be many hundred times larger than the bulk of the water from which it originated. Now in that expanded state, steam is capable of holding a vast deal more of the element of heat, than in its form of water, and that without manifesting any higher degree of temperature. Or, in other words, if a thermometer be placed in a bottle full of vapour of water, and another thermometer be placed in the water from which that vapour was just produced, their temperatures will be found to be nearly the same; yet the vapour contains a vast deal more of the element of heat than an equal weight of water, which quantity of heat is essentially necessary for maintaining its elastic or vaporous existence; and this is proved by observing, that vapour cannot be converted into water without depositing its heat upon (and of course elevating the temperature of) the surrounding bodies; and on the other hand, that water cannot be converted into vapour, without absorbing heat from (and consequently cooling) the surrounding bodies. Mr. Watt of Birmingham says, that he has observed as exact a coincidence between the heat rendered latent in the vapour, and that which emerges from it, as can be desired; and that the heat obtainable from steam, capable of sustaining the ordinary pressure of the atmosphere, is not less than 900°; and that it does not exceed 950° of Fahrenheit's scale.

The cooling action of evaporation is counteracted by the influx of heat from the surrounding bodies, since heat always tends to equalize the temperature of contiguous bodies. Thus in the above described experiment, the heat of the surrounding air tends to elevate the temperature of the

thermometer, at the same time that the evaporation from the cotton tends to lower it. And according as the one or the other of these opposite actions predominates, so the cooling effect is more or less conspicuous. From these observations it naturally follows, that the cooling, occasioned by evaporation, is greater when the evaporation is quicker, and contrarywise; also, that when different fluids are used for the evaporation, in similar circumstances, that fluid which evaporates quickest, produces the greatest refrigeration. Mr. Cavallo says, "in order to try the degree of refrigeration produced by the evaporation of different fluids, I held up a naked thermometer, (*viz.* a thermometer, the bulb of which was not in contact with the metal of the scale) and poured upon its bulb a stream of some particular fluid, which issued out of the capillary aperture of a tube; taking care to throw just fluid enough to supply the waste by evaporation. By this means, when the temperature of the air was 64° , I found that the evaporation of water cooled the thermometer 8° ; *viz.* brought it down to 56° ; the evaporation of spirit of wine cooled it 16° ; *viz.* brought it down to 48° ; and the evaporation of ether cooled it 54° ; *viz.* brought it down to 10° . But, by the use of the best purified sulphuric ether, when the temperature of the air was about 56° , I brought the thermometer down to 3° . The cooling produced by the evaporation of other fluids needs not be mentioned; their effect being generally intermediate between the effect of water, and that of spirit of wine." (Phil. Trans. vol. lxxi.) Whatever promotes the evaporation, such as a dry air, and especially a dry wind, tends to increase the refrigeration; and when all the favourable circumstances concur, the effect is prodigious; so that in a dry, warm, and brisk wind, by means of the evaporation of the best sulphuric ether, the temperature of any kind of bodies may be lowered many degrees below the freezing point; and animals might be easily frozen to death.

Though several of the above-mentioned particulars, and especially the causes upon which they depend, have been but lately investigated and ascertained; yet the cooling effect of evaporation has been known and used by mankind from time immemorial. Athenæus says, as being related by Protagorides of Cyzicum, that in the time of king Antiochus, it was usual to cool water by evaporation, and to drink it as a luxury. A very easy and familiar experiment to shew the effect of evaporation, may be performed in the following manner. Moisten a small space on the upper part of each hand; cover one of those places with an inverted wine glass, and let a person blow with a pair of bellows upon the other hand. The latter will be sensibly cooled, but not the former. Change the glass and the blowing, from one hand to the other, and the effects will be reversed. Seamen, especially in the night time, frequently employ this natural effect for discovering which way the wind blows. They moisten a finger of their hands by putting it in their mouth; then expose it to the ambient air by elevating it above their head; and justly conclude that the wind blows from that quarter which is opposed to the most cooled side of the finger.

In warm climates, where the dryness of the air generally is very great, the refrigeration arising from evaporation is very considerable, and is of course frequently employed for counteracting the natural heat. The caravans which traverse the parched deserts of Arabia, are obliged to carry their supply of water in earthen jars upon camels; but in order to keep it pleasantly cool, the jars are involved in cloths, which they take care to keep continually moistened with water. It is a pretty common practice in the

southern parts of Europe, as well as in the East and West Indies, in America, &c. to wrap up a bottle of wine, or water, or other liquor, in a wet cloth, and thus to suspend it in a shady place, either under a tree or in a passage, so as to expose it to the briskest current of air that can be obtained; for by this means the liquor will be cooled several degrees; care, however, must be had to sprinkle more water upon the cloth, which surrounds the bottle, in proportion as the former evaporates. Mr. Walker, of Oxford, describes a peculiar method of producing a very considerable degree of cold by means of evaporation. "Having," he says, "in the course of the preceding winter, frequently succeeded in producing ice, by the cold produced from evaporation with water, when the temperature of the air was 38° ; it occurred to me, that it might be possible to freeze water in the middle of summer, by a process which depended on this principle, by the use of water only. Accordingly, I procured a tall cylindrical vessel, holding about two gallons, in which is fixed a small spiral tube, as in the worm-tub of a common still; the lower end of this tube comes out through the vessel near the bottom, sufficient to connect the nose of a pair of bellows to it, by the intervention of a bladder, secured air-tight; this spiral tube ends at the top of the cylindrical vessel, where it is somewhat enlarged, like the mouth of a funnel. This vessel, being covered with flannel, was filled with water and hung out in a brisk dry wind, the temperature of the air being 50° ; after some time, by repeatedly wetting the flannel on the outside of the vessel, I found the water within was cooled to 40° ; air being then forced through the tube (by means of the bellows), surrounded by the cooled water, came out at the upper extremity of the tube at nearly the same temperature.

"A thermometer having its bulb covered with lint, and wetted repeatedly with the cold water in the vessel, placed so as to receive the draught of cold air from the tube, soon sunk to 34° ; hence by a series of two or three of these vessels, water might, upon this principle, be frozen at midsummer, recollecting that this experiment may always commence at 50° , the usual temperature of springs; and hence it might be possible upon the same principle, to cause nature upon a small scale, even without the immediate interposition of art, to depart from her usual course, and to assume the hoary garb of winter at midsummer.

"For this purpose a current from the external air might be admitted into the tube, by means of a funnel, communicating with, and receiving, a constant draught of air.

"In an attempt of this kind, it would be necessary (besides some other variation in the vessels, which circumstances might point out,) that the cylindrical vessels be porous, or pierced with small holes; so that the water may be constantly and gently oozing out."

In Spain, in Italy, in Egypt, and probably in other places, certain vessels are made of a porous earth, which, when full of water, will just permit some of that fluid to ooze out on their external surface, whence it evaporates, and thus cools the remainder of the liquor within the vessel. The Spanish vessels for this purpose consist of a reddish brown earth. They are pretty broad, but not very capacious. In Italy they have been made of a pale yellowish material, but much larger. In Egypt they are made somewhat in the shape of a Florence flask, and not much bigger; but their aperture spreads out in the form of a cone, or rather of an ale glass, which is done for the convenience of drinking out of it. Their substance is of the colour of asbes, and it is said to be a scum left on the banks of rivers. But vessels of any degree of porosity may be made by mixing sand and clay in various proportions.

The use of these vessels in Spain, in Italy, and especially in Egypt, is attended with a notable degree of refrigeration, on account of the great dryness of the air in those climates, which enables it to absorb a great deal of moisture in a short time; but the same vessels having been brought over, and having been tried, in this country, have been found to cool the contained liquor in a very trifling degree; evidently owing to the state of the air in this country, which is much less hot, and much less dry than in the above-mentioned places; therefore much less apt to promote evaporation. One of the Egyptian vessels was tried in London at a time when the temperature of the atmosphere was at a mean, and after about half an hour, when almost three quarters of the water had passed through it, and had dropped down, the remaining quantity of water was found barely 3° colder than the surrounding air.

It is but lately that liquor coolers have been manufactured in this country, and they are at present to be found in most of the earthenware shops in and about London. These are cylindrical vessels, about six inches in diameter, and about a foot high. It is directed to keep one of these vessels entirely immersed in water during one hour. The vessel, being then removed, in that moist state, without putting any water in it, a bottle of wine, &c. must be placed in it, and this is said to be cooled by the evaporation of that quantity of water, which the substance of the vessel had imbibed whilst it remained under water. Upon trial, however, it appears that the actual refrigeration which is obtained by means of one of these vessels, seldom amounts to two or three degrees; and that, of course, a bottle of wine may be cooled much more effectually by placing it into a pail of water fresh drawn from a pretty deep well or pump; which may be renewed at intervals. Indeed, considering the form of these coolers, also that the sides of it are at a considerable distance from the surface of the bottle, and the ambient air has a free access to both, it is hardly to be expected that any sensible advantage should be obtained from them.

In India the action of evaporation is used not only for cooling liquors, but likewise for cooling apartments, and the effect, by the testimony of those persons who have experienced it, is said to be very remarkable. The method, (which, however, is practicable only when a dry wind blows,) is as follows. That door of the apartment which is opposed to the wind, and through which the wind enters, is stopped up with a peculiar sort of screen or curtain, which fits it exactly. This screen consists of two surfaces or gratings of bamboo, situated parallel to each other, and about three or four inches apart; then the space between these external surfaces is filled up in a loose manner with the roots of a sweet-scented grass. In short the construction of this screen is calculated to admit the air not in a body, but divided through a vast number of passages. Two men are placed on the outside, each having a goat's skin filled with water, which they keep continually sprinkling upon the screen. A constant and copious evaporation is of course kept up, which presently cools the adjoining room to a very remarkable degree. By this means the temperature of the room has sometimes been lowered upwards of 15° .

Amongst those cooling processes which depend upon the expansion of bodies, that which arises from the expansion of air must not be forgotten; but as this is by no means very practicable, we shall barely mention it in this place. The condensation and expansion of air produce the effects which have been mentioned above; viz. the former is attended with an extrication of heat, and the latter with an absorp-

tion of it; hence the contiguous bodies are heated by the former, and are cooled by the latter. When air is suddenly condensed, (see CONDENSER, and CONDENSATION,) the heat which is extricated from it, has been found capable of setting fire to light combustible bodies; and when the air is rarefied either by means of an air-pump, or by liberating it from a vessel, in which it has been condensed; the cold it produces has sometimes been found to lower the thermometer several degrees below the freezing point.

The last method of cooling which remains to be described, is obtained by the solution of salts. That certain saline substances, whilst dissolving in water, or in acids, would generate a considerable degree of refrigeration, and especially that the solution of salt ammoniac would lower the thermometer down to the freezing point, has been long known; but, within these 15 or 20 years, the subject has received wonderful improvements, in consequence of the experiments instituted by various ingenious persons; and especially from the assiduous investigations, and successful experiments of Mr. Walker of Oxford, who has examined the cooling powers of a vast number of saline substances both single and mixed; and has been able to freeze quicksilver at Oxford in the middle of summer, merely by the solution of salts. His interesting experiments, and his various freezing mixtures, will be found described under the article FREEZING.

A vast number of salts and saline mixtures may be used for cooling liquors; but the most advantageous are those which, after solution, may be recovered by means of evaporation, so as to render them useful for a second refrigeration, a third, and so forth. Yet the price of most of those salts in Europe, the trouble of recovering them from the solution, and pounding them in order to render them fit for another cooling operation, have not rendered this method common in this part of the world; especially where other easier methods are practicable. So that in fact the cooling power of saline solutions is mostly used for particular experiments by the European philosophers, especially when a very powerful freezing mixture is required. In India, where nitre is very cheap, and the heat of the climate prompts the inhabitants eagerly to adopt every possible method of cooling, the practice of cooling liquors, by means of the solution of nitre in water, is very common. For this purpose, the wine, the water, or any other liquor, is put into a metallic bottle, generally a pewter one, having a pretty long neck. A tub is partly filled with water, and a quantity of nitre is thrown in it; then the operator holds the bottle by the upper end of its long neck, and gently moves it about the saline solution, and thus cools the liquor in it to a very considerable degree. As salts will produce cold only during their solution, therefore when the first quantity of nitre has been thoroughly dissolved in the above process, more nitre must be added; and when the water is completely saturated, so as not to be capable of dissolving more salt, then the bottle must be removed to another tub with a fresh saline mixture. The nitre might afterwards be easily recovered merely by exposing the solution, in shallow pans, to the hot rays of the sun in that country; this economical plan, however, does not as yet seem to have been adopted.

The salts which might be used for the purpose of cooling liquors in this country, or in long voyages, are nitre and salt ammoniac; the other saline substances being either more expensive or not easily recoverable after solution. Of the effects of nitre alone in water enough may be derived from the above described process. Salt ammoniac by itself

gradually added to a quantity of water, will occasion a considerable refrigeration, so that a bottle of wine, &c. placed in the solution may be cooled even to 32° of Fahrenheit's scale. But a mixture of both salts is much more efficacious, and the best proportion is five parts of nitre, five of salt ammoniac, and 16 of water. During the solution, which will continue a considerable time, this mixture will cool the thermometer several degrees below the freezing point; but it must not be imagined that a small quantity of the same will cool a bottle of wine to an equal degree. The solution of a given quantity of the mixture absorbs a certain quantity of heat, and this quantity abstracted from the small body of the thermometer, will lower its temperature considerably; but the same quantity of heat abstracted from a bottle of wine, will cool it proportionably less than the thermometer. In order to cool a bottle of wine from the usual temperature of spring waters (which in London is about 50° or 51°) down to about 32° ; a pound of nitre with a pound of salt ammoniac, and a proportionate quantity of water, will generally suffice. The salts for this purpose must be finely powdered and as dry as possible. But when a moderate refrigeration is required; half a pound of each salt and about three pints of water will be sufficient.

Glauber salt, (*viz.* sulphate of soda) dissolved in water, likewise produces a very considerable refrigeration; but this salt will not produce that effect unless it be in its crystallized state. In that state, however, it is not easily preserved, since the mere contact of air will render it powdery and opaque, in which case its solution will generate heat rather than cold. On this account, therefore, this salt is not so much to be recommended, as those which have been already mentioned. Nearly the same observations are applicable to the muriate of lime, the solution of which saline substance, when properly conducted, has a very powerful cooling property.

Thus we have described all the practicable processes of cooling, which, if not in this country, are undoubtedly of great consequence amongst the inhabitants of warmer climates. We have, likewise, stated the most necessary particulars respecting the quantity of materials proportionate to the effect, whence the intelligent reader may be enabled to make proper choice of a process fit for his purpose, agreeably to the circumstances which the nature of the place, the actual temperature of the atmosphere, and other particulars, may offer.

There are now two other particulars belonging to the present article which deserve to be briefly mentioned. The first is that by cooling, certain bodies acquire electrical properties; and the second is that the law of cooling, or progress of refrigeration, furnishes a method of measuring such high degrees of heat, as exceed the scale of ordinary thermometers.

With respect to the first, it has been observed that sulphur, in cooling after having been melted, becomes electrified, so as to attract and repel small light bodies like any other excited electric. The same thing also takes place with wax, chocolate, and a few other substances. Besides this effect of cooling after fusion, there are certain solids, like the tourmalin, the Brazilian emerald, &c. which are rendered electrical by any alteration of their temperature, be it from cold to heat, or from heat to cold; but for a full and particular account of those facts, which properly belong to the science of electricity, see the articles **ELECTRICITY, ELECTRICS, and EXCITATION.**

The method of determining high degrees of heat, from the progress of cooling, depends upon the following observation. Sir Isaac Newton, considering the progress of cooling, was led to suppose, that the heat lost by any body originally at a high temperature, in equal small portions of time, is as the heat existing in it; (reckoning the heat in the body, equal to its excess above that of the surrounding atmosphere,) that is, taking the times in arithmetical progression. The portions of heat lost in those times would be in a geometrical one. The truth of this supposition has been sufficiently shewn by subsequent experiments, the result of which has not differed much from the theoretical determinations. Hence we have the following practical rule for determining the high temperature to which a body has been exposed, from its subsequent progress of cooling.

Measure the time in minutes that elapses from the hottest state of the body (which is the degree sought,) to such a state of lower temperature as will allow the application of a common thermometer to the body in question, and call this number of degrees *A*; then having applied the thermometer, set down the temperature, which is indicated by the same, at the expiration of each successive minute, until you have obtained three or four terms of the series, which, as has been said above, will be found to be a geometrical one (omitting, however, trifling differences.) Now, since from those few terms it is easy to determine any other terms of the same series, by the well known arithmetical rules; find so many terms of the series ascending, as are equal to the number of units in *A*; and the last term of the series, thus found, will be the degree of temperature of the body in its hottest state. An example will easily illustrate the application of this rule. Suppose it be required to determine the temperature of a piece of red-hot iron at the time that it came out of the forge. Look at the watch the moment the iron is taken out of the fire, and note the minute. Find by trials when the thermometer may be safely applied to the iron, *viz.* when the heat is not sufficient to rarefy the mercury of the thermometer beyond the limit of its scale, and when this is practicable, observe the temperature of the iron, and the corresponding time as indicated by the watch. Suppose, for instance, that when the temperature of the iron was 250° , four minutes had elapsed since the commencement of the observation; therefore in this experiment *A* is equal to 4. Let the thermometer continue in contact with the iron, and when one minute more has elapsed, let the temperature be 125° . When another minute has elapsed, let the temperature be $62\frac{1}{2}$ degrees; and after this, the observation needs not be continued. Now we have three successive terms of a geometrical series; *viz.* $62\frac{1}{2}$, 125, and 250; from which four more terms of the series are to be found, (since *A* was found equal to 4,) and the last of those terms is the number of degrees indicating the temperature sought. By dividing 250 by 125, or the latter by $62\frac{1}{2}$, we have the quotient 2, (or nearly 2) which is the multiplier of the series, and therefore multiplying 250 by 2, we have the term 500, which multiplied by 2, gives the next term 1000, which multiplied by 2, gives 2000; and lastly this term multiplied by 2, gives the fourth term 4000; hence we conclude, that when the iron was taken out of the furnace, its temperature was 4000 degrees. The last term of the series may be found out by other means, but we have chosen the easiest, for the convenience of all readers. The two series are annexed.

Time elapsed in minutes.	Corresponding heat.
0.	4000°.
1.	2000.
2.	1000.
3.	500.
4.	250.
5.	125.
6.	62½.

Instead of minutes, the intervals of time may be half minutes, or hours, or, in short, of any other denomination; provided they be all equal.

COOLING of liquors, in *Domestic Economy*, is a practice of ancient origin, and of general prevalence in warm countries, and, during the heat of summer, even in colder climates. This practice, as some have thought, is referred to by Solomon, in the book of Proverbs (ch. xxv. 13.); but however this be, evidences of it are very numerous in the works of the Greeks and Romans. Ice and snow were generally used for this purpose, and repositories were constructed for keeping these cooling materials. That the snow was preserved in pits or trenches is asserted by many; particularly by Seneca (*Quæst. Natur.* iv. 13.) and Pliny (*H. N.* l. xix. 4.) When Alexander the Great besieged the city of Petra, he caused thirty trenches to be dug, and filled with snow, which was covered with oak-branches, and which was kept in that manner for a long time (*Athenæi Deipnos.* iii. p. 124.) Plutarch says (*Sympos.* vi. *Quæst.* 6.), that a covering of chaff and coarse cloth is sufficient; and a like method is now practised in Portugal. Where the snow has been collected in a deep gulph, some grafs or green sods, covered with dung from the sheep-pens, are thrown over it; and under these it is so well preserved, that it is sent through the whole summer for the distance of 60 Spanish miles to Lisbon. When the ancients wished to have cooling liquors, they either drank the melted snow, or put some of it in their wine, or they placed jars filled with wine in the snow, and suffered it to cool there as long as they thought proper. The dissipated and luxurious Heliogabalus caused whole mounts of snow to be heaped up in summer to cool the air (*Lamprid. Vit. Heliogab.* c. 23.) That ice was also preserved for the like purpose is probable from the testimony of various authors, Pliny, Seneca, &c.; but it appears not to have been used so much in warm countries as in the northern. At present snow is employed in Italy, Spain, Portugal; but in Persia, ice. The art of cooling water without snow or ice was soon suggested to mankind, by observing, that it became cold more speedily when it had been previously boiled, or at least warmed, and then put in a vessel among snow, or in a place much exposed to the air. Pliny (*H. N.* l. xxxi. 3. 23.) seems to ascribe this to the invention of Nero; and a jocular expression of Suetonius (*Vit. Ner.* c. 48.) renders it probable, that he was fond of water thus cooled. But this method was much more ancient than Nero; for it seems to have been known to Hippocrates (*De Morb. Vulgar.* lib. vi. 4.); and Aristotle was acquainted with it; for he says (*Meteorol.* i. cap. 12.) that some were accustomed, when they wished water to become soon cold, to place it first in the sun and suffer it to become warm. He relates also, that the fishermen near the Black Sea poured boiling water over the reeds, which they used in fishing on the ice, to cause them to freeze sooner. See also Galen, in lib. vi. *Hippocrat. de Morb. Vulg.* Comment. 4. 10. Athenæus remarks (*Deipnos.* iii.) that the pitchers filled with water, which had become warm by standing through the whole day in the sun,

were kept continually wet during the night, by servants destined to that office, and in the morning they were bound round with straw. In the island Cimolus, water which had become warm in the day-time was put into earthen jars, and deposited in a cool cellar, where it became as cold as snow. From these facts it appears to have been a general opinion, that water which had been warmed or boiled, was soonest cooled, and acquired a greater degree of refrigeration. The same opinion prevails at present in the southern countries of Asia, and persons there let their water boil before they expose it to the air to cool. The experiments, however, that have been made on this subject, have given different results. Beckmann (*ubi infra*) inclines to the opinion, that the cooling of water in ancient times is not to be ascribed so much to the boiling as to the keeping of the jars continually wet, and to the air to which they were exposed. See CONGELATION and FREEZING, and also the preceding article.

Another method of cooling water seems to have been known to Plutarch. It consisted in throwing into it small pebbles or plates of lead (*Sympos.* vi. 5.)

The practice of cooling liquors, at the tables of the great, was not usual in any country besides Italy and the neighbouring states, before the end of the 16th century. In the middle of that century, there were no ice-cellars in France. Towards the end of this century, under the reign of Henry III., the use of snow must have been well known at the French court, though it appears that it was considered by the people as a mark of excessive and effeminate luxury. Towards the end of the 17th century, this luxury must have been very common in France. At that period there were many who dealt in snow and ice; and that was a free trade which every one might carry on: but soon after government farmed out a monopoly of cooling waters.

The method of cooling liquors by placing them in water, in which salt-petre has been dissolved, could not be known to the ancients, because they were unacquainted with that salt. This property of salt-petre was first discovered in the first half of the 16th century; and it was not remarked till a long period afterwards that it belongs also to other salts. The Italians were the first persons by whom it was employed; and about the year 1550, all the water, as well as the wine, drunk at the tables of the great and opulent families at Rome, was cooled in this manner. Towards the end of the 16th century this method of cooling liquors was well known. Mr. Beckmann says, that he cannot determine who first conceived the idea of mixing snow or ice with salt-petre, and other salts, which increase the cold so much, that a vessel filled with water, placed in that mixture, is congealed into a solid mass of ice, that may be used on the table, but the earliest account of it he has been able to find is in a work of Latinus Tancredus, a physician and professor at Naples, who, in his book, "*De Fame et Siti*," published in 1607, speaks of this experiment. In 1626 Sanct. Sanctorius, in his Commentary on the Works of Avicenna, relates, that, in the presence of many spectators, he had converted wine into ice, not by a mixture of snow and salt-petre, but of snow and common salt. When the salt, he says, was equal to a third part of the snow, the cold was three times as strong as when snow was used alone. Lord Bacon, who died in 1626, says, that a new method had been found out of bringing snow and ice to such a degree of cold, by means of salt-petre, as to make water freeze. This, he tells us, can be done also with common salt; and he adds, that in warm countries, where snow was not to be found, people made ice with salt-petre alone; but that he had never tried the experiment. Mr. Boyle, who died in 1691, made experiments with various

kinds of salt ; and he describes, how, by means of salt, a piece of ice may be frozen to another solid body. Des Cartes says, that, in his time, this was a well-known phenomenon, but highly worthy of attention. Since that period, the art of making ice has been mentioned in the writings of all philosophers, where they treated on heat and cold. Towards the end of the 17th century, the French began to congeal

all kinds of well-tasted juices, which were served up as refreshments at the tables of the great and wealthy. This was a grand invention for the art of cookery, and afterwards it became common, especially in the last century, and since that time the confectioners have universally practised it. Beckmann's Hist. of Inventions, vol. ii. See FREEZING and ICE.

Copal

COPAL. This valuable and singular kind of resin is imported partly from South America, and partly from the East Indies, and like most of the other resins, is a natural exudation from a large tree, which hardens in the air.

The best copal is a hard brittle resin, in rounded lumps of moderate size, easily reducible to fine powder, beautifully transparent, but often, like amber, containing parts of insects and other small extraneous bodies impacted in its substance.

The colour of copal is a light lemon yellow, varying to orange; but when dissolved and thinly spread over any surface, the colour is scarcely perceptible, and it only gives a fine hard, smooth, transparent glazing. It is this union of hardness and transparency, with want of colour, that renders copal so valuable as a varnish.

Copal unquestionably belongs to the class of resins, but it differs from most of these substances in the great difficulty with which it dissolves in alcohol and essential oils, so as to require great purity of these menstrua and particular management.

The three menstrua usually employed in varnishing, are alcohol, oil of turpentine, or any other essential oil, and drying linseed, or other fixed oil. These are used sometimes separately with the varnish resins, but generally mixed.

We shall give some of the processes by which copal may be dissolved in each of these substances.

Alcohol singly, which so readily dissolves the other resins, has but little action on copal; for if this resin in fine powder be digested with the very purest alcohol, with or without heat, scarcely any of it is dissolved, and the copal coalesces at the bottom of the vessel into a tough cohesive mass. But a solution may be effected by the addition of *camphor*, the action of which, upon the resins, has been partly described under that article. With none is it more striking than with copal. When the two are separately powdered and mixed, the copal absorbs the camphor, swells and softens into a pasty mass, which will remain for months of the same consistence, without hardening. To make an alcoholic solution of copal, dissolve half an ounce of camphor in a pint of highly rectified alcohol; put it in a glass vessel over a lamp, and add four ounces of copal in small pieces, and continue the heat just to that degree at which the bubbles may be counted, till the solution is complete. Part of the copal separates when cold, but most of it remains in permanent solution.

It is necessary first to dissolve the camphor in the alcohol; for, if the pasty mass arising from the mixture of copal and camphor be added to alcohol, the solution will not go on.

A mixture of mastic, elemi, and other resins, will bear a moderate quantity of copal, without being rendered insoluble in alcohol, even without the assistance of camphor.

To dissolve copal in the essential oils, Mr. Sheldrake has given the following process in the *Transactions of the Society of Arts*.

Reduce two ounces of copal to *coarse* powder; put it into a glass vessel, and pour thereon a pint of the *very best*

oil of turpentine, with one eighth of spirit of sal ammoniac, previously well shaken. Cork the glass, leaving a pin-hole through the cork to allow of the escape of vapour, and speedily heat it to that point at which the bubbles may be counted. Continue this till the solution is complete, taking care not to increase the heat, otherwise the copal will coalesce at the bottom of the glass, and the solution will not go on. The vessel should not be opened till quite cold. This liquor is of a rich deep yellow when in quantity, but when applied as a varnish, it is nearly colourless. The spirit of sal ammoniac is not a necessary ingredient.

Mr. Tingry of Geneva (*Painter's and Varnisher's Guide*, 1804,) finds that copal may be united to oil of turpentine by the intermede of some other of the essential oils, particularly oil of spike and lavender. He gives the following process: Take two ounces of oil of lavender, heat it in a glass matras, add thereto an ounce of copal grossly powdered, and, at different times, stirring the mixture with a stick of white wood. When the copal is dissolved, add six ounces of oil of turpentine, nearly boiling, and stir the whole thoroughly. This gives a fine gold-coloured liquid, very fit for varnishing.

Camphor also highly assists the solution of copal, in oil of turpentine, as it does in alcohol, and the same precaution is necessary, of dissolving the camphor completely in the oil, before the copal is added. Half an ounce of camphor is sufficient to a quart of the oil, to enable it to take up as much copal as will make a good varnish.

To unite any of the resins with drying linseed oil in the composition of the oil varnishes, it is necessary to expose them to a much greater heat than in the former instances, that is, not less than is sufficient to liquefy the resins. This, however, always gives the resin a certain degree of brown colour, which is often injurious to it when used as a varnish. Copal when melted with as little heat as possible, and then dropped into drying linseed oil, dissolves therein with ease, and this solution mixed with clear turpentine, forms a very fine hard varnish. To avoid as much as possible the discolouration of the copal, Mr. Tingry incloses it in a kind of wire-cage suspended in a very slow well-regulated furnace; and, as soon as any portion melts, it falls in drops into the drying oil heated and set beneath it.

When melted copal is dropped into water, a small quantity of oil is separated, and floats at top, and the resin at the bottom is thereby rendered somewhat more soluble in the different menstrua.

Copal is liable to be confounded with gum anime, when the latter is very clear and good. The distinction is of some consequence, as the anime, though valuable in varnishing, is much less so than the finest copal, the varnish with the former being darker coloured, and not so hard. Besides the external appearance of each, which is pretty distinct to a practised eye, the solubility in alcohol furnishes an useful test, the anime being readily soluble in this fluid, but the copal scarcely so.

Copper

COPPER, *Kupper*, Germ. *Cuivre*, Fr. *Cuprum*, *Aes*.
Lat. *Venus*, Alchem.

Copper is a ductile and malleable metal, of a pale yellowish red colour. It is soluble in most acids, and is precipitable from them in the metallic state, by iron or zinc: its oxyd is soluble in ammonia, to which it communicates a bright blue purple colour.

§ 1. Ores of Copper.

Sp. 1. Native copper. *Gediegen Kupper*. *Cuivre natif*.

Its colour is a clear copper-red, often tarnished, externally yellowish, blackish, or whitish.

It occurs in mass, disseminated, in leaves and grains, also capillary, moss-like, dendritical and crystallized. The regular forms that it presents, are the cube, the octohedron, and the pyramidal dodecahedron often with a short six-sided prism interposed.

The crystals are small, and generally implanted in each other, forming clustered masses. Its lustre internally is glistening and metallic; its fracture is hackly: when cut or rubbed, it acquires a high metallic lustre. It is not very hard, is malleable and flexible, but not elastic, is tough and

difficultly frangible. Sp. gr. 7.72.—8.53.

It is fusible before the blow-pipe, and appears to be pure copper.

It occurs in veins and beds in various primitive and secondary mountains, accompanied by many of the other ores of copper, also by galena, horn silver, native silver, calcareous, heavy, and fluor spars.

It is very extensively, but not very abundantly, diffused; the largest masses appear to be procured from the copper mine river, within the arctic circle in North America; it is also of frequent occurrence in Japan and Brazil, in Siberia, Hungary, Norway, Sweden, Saxony, and Cornwall.

Sp. 2. Vitreous copper. *Kupperglas*. *Cuivre vitreux*.

Its colour is dark lead-grey, passing into blackish-grey; it is often covered superficially by a steel-coloured tarnish. It occurs in mass, disseminated or crystallized. The forms of its crystals are the cube, the octohedron, and a hexahedral prism, sometimes terminated by trihedral summits. The crystals are small; externally they are shining, internally they exhibit a glistening metallic lustre. The fracture is fine-grained, uneven, passing into conchoidal. It gives a

shining streak, is blackish when pulverized; is somewhat brittle, and easily frangible. Sp. gr. 4.1.—5.4.

It effervesces with nitrous acid, and when exposed to the blow-pipe, gives a metallic button of a steel-grey colour, and generally attractable by the magnet.

When pure, it appears to be a simple sulphuret of copper, consisting, according to Chenevix, of

81 Copper
19 Sulphur

100

It is generally however mixed with iron in the proportion of from 3 to 6 per cent. A specimen from Siberia was analyzed by Klaproth, and afforded

78.5 Copper
18.5 Sulphur
2.25 Iron
0.75 Silica

100.

It occurs in veins and beds in primitive and secondary mountains, accompanied by copper pyrites, and other ores of this metal. It is not very abundant, but is found in various places, especially Cornwall, Hungary, Saxony, Norway, and Siberia.

Sp. 3. Variegated copper. *Buntkuppererz*.

Its colour is intermediate between copper-red, and Tom-hac brown; by exposure to the air it acquires a superficial tarnish, which is first reddish, then violet, afterwards blue, and lastly green. It occurs in mass, disseminated, superficial, or crystallized in octahedrons. Internally it is shining, with a metallic lustre. Its fracture is small, and imperfectly conchoidal, passing into fine-grained, uneven. It takes a polish by friction, and gives a reddish coloured streak. It is soft, somewhat brittle, and easily frangible. Sp. gr. 4.9. 5.4.

It effervesces with nitrous acid, and melts readily before the blow-pipe, without vapour or odour. Two specimens, the one from Hitterdahl in Norway, and the other from Rudelsdorf in Siberia, have been analyzed by Klaproth, with the following results.

Hitt.	Rud.
69.5	58. Copper
19.	19. Sulphur
7.5	18. Iron
4.	5. Oxygen
100.	100.

This ore occurs in beds, veins, and disseminated through rocks, for the most part belonging to the class of primitive. It is usually accompanied by vitreous copper, and copper pyrites. It is found in Cornwall, in Hungary, Saxony, Norway, and Sweden.

Sp. 4. Copper pyrites. *Kupperkies*. *Pyritis cuivreuse*.

Its colour is deep brass-yellow, passing into gold-yellow. Its surface is often iridescently tarnished. It occurs in mass, disseminated, superficial, stalactical, clustered, reniform and crystallized in tetrahedrons, and the derivative octahedron, and dodecahedron. The crystals are usually very small and imperfect. The surface of the crystals is smooth and shining; that of the other varieties is rough and glimmering. The fracture is coarse or fine-grained, uneven, passing into conchoidal, and imperfectly foliated. It is

brittle, and with difficulty gives a few feeble sparks with the steel; it may be readily cut by a knife. Sp. gr. 4.—4.1.

When exposed to the blow-pipe on charcoal, it decrepitate, emits a sulphureous vapour, and melts into a black globule, which, by further application of the heat, acquires the colour and lustre of copper. It does not appear that the crystallized varieties of this ore have been regularly analyzed, and the proportion of its constituent parts cannot be estimated from the other varieties, on account of the iron pyrites, with which they are always more or less mixed. A specimen analyzed by Lampadius afforded

41. Copper
17.1 Iron
45.1 Sulphur

103.2

The richer this ore is in copper, the softer it is, and its colour approaches the more to that of gold. It seldom, however, in the large way, affords more than 20 per cent. of copper. It may readily be distinguished from iron pyrites (the only substance with which it is likely to be confounded) by the pale brass yellow colour, and superior hardness of the latter.

Copper pyrites is the most abundant, and most generally diffused of any of the ores of this metal. It occurs in veins and beds in primitive, transition, and secondary rocks, in most countries of the world.

Sp. 5. White copper. *Weisse Kuppererz*. *Mine de cuivre blanche*.

Its colour is intermediate between silver-white and brass-yellow. It occurs in mass or disseminated. Internally it has a slight metallic lustre. Its fracture is small, and fine-grained uneven. It yields readily to the knife, is brittle, and easily frangible. Sp. gr. 4.5.

Before the blow-pipe it yields a white smoky, and an arsenical odour, and melts into a blackish slag. According to Henckel it yields about 40 per cent. of copper, the rest being iron, arsenic, and sulphur.

It occurs in veins and beds, in primitive mountains, and is generally accompanied by copper pyrites and vitreous copper.

It is found in Cornwall, Saxony, Silesia, Hungary, Siberia, and Chili in South America.

Sp. 6. Grey copper. *Fahlerz*. *Cuivre gris*.

Its usual colour is steel-grey, which passes into iron-black and lead-grey; some varieties incline towards yellow and others again present superficial iridescent colours. It occurs in mass, disseminated or investing, or crystallized in regular tetrahedrons and their modifications. The crystals are small, with shining surfaces. Internally it is glistening, or shining with a metallic lustre. The fracture is coarse, and small-grained, uneven, inclining to imperfectly conchoidal. It gives a black or reddish-brown powder. It is moderately hard, brittle, and easily frangible. Sp. gr. 4.46.—4.36.

The only necessary ingredients of this species (as appears from an analysis by Chenevix; of the crystallized variety) appear to be copper, iron, and sulphur in the following proportions, viz.

52 Copper
33 Iron
14 Sulphur

99

The uncrystallized varieties, however, generally contain also antimony, silver, and lead, but in very variable propor-

sions. In several varieties from Germany, Mr. Chenevix found antimony varying in proportion from 5 to 38 per cent. but neither lead nor silver. Two specimens, the one from Andreasberg, and the other from Crannitz, have been analyzed by Klaproth with the following results.

Copper	31.36	16
Iron	3.3	13
Sulphur	11.5	10
Antimony	34.09	16
Silver	14.77	2.25
Lead	0.	34.
Silex	0.	2.5

95.02 93.75

Finally, a specimen from Piedmont has been examined by Napione, and found to consist of

Copper	29.3
Iron	12.1
Sulphur	12.7
Antimony	36.9
Silver	0.7
Arsenic	4.
Alumine	1.1

96.8

Those specimens that give a reddish-brown streak, are generally the most abundant in silver.

It occurs in veins in slate, and some other of the newest primitive rocks, and in beds in the transition and floetz rocks. It is accompanied by copper pyrites, galena, manganese, spathose iron, and rarely by malachite. When it contains a notable proportion of silver, it is considered and worked as an ore of this metal.

It is found in Cornwall, and in the county of Ayr in Scotland; also in Bohemia, Hungary, Transylvania, Saxony, Hesse, the Hartz, France, Spain, Piedmont, Sweden, Norway, Siberia, and Chili.

Sp. 7. Black copper. *Kupperchwartze. Cuivre noir.*

Its colour is intermediate, between blueish and brownish black. It occurs in mass, disseminated or investing. It is composed of dull moderately cohering particles. It is friable, slightly soils the fingers, is meagre to the feel, and heavy.

Before the blow-pipe it emits a sulphureous odour, and melts into a slag that colours borax green. It has not been regularly analyzed, but is said to contain from 40 to 50 per cent. of copper.

It occurs with other ores of copper, particularly copper pyrites, malachite, mountain green, and vitreous copper.

It is found of remarkable beauty, at Kupperberg, in Silesia, also in Saxony, Hungary, Norway, and Siberia.

Sp. 8. Ruby copper. *Roth. Kuppererz. Cuivre oxydé rouge.*

Of this species, there are the three following varieties.

Var. 1. Lamellar.

Its colour is dark cochineal red, inclining sometimes to lead-grey; when crystallized it is often of a full carmine red. It occurs in mass, disseminated and crystallized in cubes, and aluminiform octohedrons. The crystals are small, and for the most part laterally aggregated; their surfaces are smooth and shining. Its internal lustre is more or less shining, and is intermediate between metallic and adamantine. Its fracture is imperfectly foliated, passing into granular uneven. When in mass it is usually opaque, or at most translucent on the edges; the

crystals are transparent, verging into translucent. It gives a brownish brick-red streak, is moderately hard, brittle, and easily frangible. Sp. gr. 3.95.

By exposure to the blow-pipe on charcoal, it is easily reducible to a metallic bead, without emitting either odour, or smoke. It dissolves in the nitrous and muriatic acids, in the former with, and in the latter without, effervescence. According to Mr. Chenevix, it consists of

88.5 Copper
11.5 Oxygen

100.

It is met with chiefly in veins, and appears to be peculiar to primitive mountains. It is accompanied by native copper and other ores of this metal. It is found in Cornwall, in Hungary, Saxony, the Hartz, Siberia, Peru, and Chili.

Var. 2. Capillary.

This variety differs from the preceding in being of a somewhat lighter colour, superior lustre, and being composed of small capillary crystals and thin flakes.

Var. 3. Compact.

It occurs in mass and disseminated, but never crystallized. Its internal lustre is glimmering, semi-metallic: its fracture is even; and it is opaque. In other respects it agrees with var. 1.

Sp. 9. Tile-red copper. *Ziegelerz.*

This species presents two varieties, indurated and earthy.

Var. 1. Indurated.

Its colour is intermediate between hyacinth and brownish-red, passing on the one hand into lead-grey, and on the other into reddish-brown. It occurs massive and disseminated. The reddish kind has a glimmering lustre and flat conchoidal fracture; the browner kind has a somewhat resinous lustre and a small conchoidal fracture. It acquires a lustre by friction, is moderately hard and brittle.

When exposed to the blow-pipe it becomes black, and is infusible without addition. Borax is tinged by it of a dirty green. It appears to be an intimate mixture of compact ruby copper with brown iron ochre, and its produce of copper varies from 10 to 50 per cent.

It occurs in veins with ruby copper, malachite, copper pyrites, and iron ochre.

Var. 2. Earthy.

Its colour is hyacinth-red, passing into reddish or yellowish brown. Its texture is between friable and solid. It occurs in mass, disseminated, and investing copper pyrites. It is without lustre, has an earthy fracture, and slightly soils the fingers. In its other characters it agrees with the preceding variety.

Sp. 10. Mountain blue. *Kupperlazar. Cuivre carbonaté bleu.*

Of this there are the two following varieties.

Var. 1. Radiated.

Its principal colour is sky-blue, which passes into Prussian and indigo-blue. It occurs in mass, disseminated or investing, more frequently botryoidal, stalactitic, and cellular, but most frequently crystallized in oblique rhomboidal prisms or octohedral prisms with dihedral summits. The crystals are generally very small and aggregated into globular masses or bundles. The crystallized varieties are externally shining, but the rest are dull. Internally it is shining or glittering, with a lustre between vitreous and resinous. Its fracture is straight or divergingly radiated, rarely lamellar. The crystals are translucent and semi-transparent, the other varieties

are opaque, or at most translucent on the edges. When pulverized it is of a sky-blue colour. It is soft, brittle, and easily frangible. Sp. gr. 3.2.—3.4.

It is very difficult of fusion before the blow-pipe, *per se*; but with borax it gives a bright green glass, and a metallic globule.

According to Pelletier it consists of

66	to	70	Copper
18	—	20	Carbonic acid
8	—	10	Oxygen
2	—	—	Water

Var. 2. Earthy.

Its colour is smalt-blue: it occurs rarely in mass, generally disseminated or superficial: it is composed of fine pulverulent cohering dull particles. Its fracture is fine-grained earthy, passing into even and imperfectly conchoidal. It is opaque, slightly stains the fingers, and is easily frangible.

Before the blow-pipe it becomes black, but does not melt. In borax it dissolves with great ebullition, and forms a green glass.

Mountain-green occurs in the newer primitive rocks, but more commonly in floetz mountains. It accompanies other ores of copper, especially malachite, grey copper, and copper pyrites. The most beautiful specimens come from the Bannat in Hungary, and from Siberia. In the Tyrol it is found in sufficient plenty to be manufactured into the pigment called mountain-blue.

Sp. 11. Malachite.

Of this there are the two following varieties.

Var. 1. Fibrous.

Its common colour is grass-green passing into emerald-green, and sometimes into dark leek-green. It seldom occurs massive or disseminated, but generally inverting, and often crystallized in short capillary needles, disposed in divergent bundles, or stars. Externally they are shining, but internally only glistening with a silky lustre. Its fracture is delicate, diverging fibrous, passing into coarse fibrous. It is opaque or translucent on the edges; the crystals are for the most part translucent. When pulverized it retains its colour, only the tint is somewhat lighter. It is very soft, brittle, and easily frangible. Sp. gr. 3.5.

It effervesces with acids, and forms a blue solution with ammonia. Before the blow-pipe it blackens and decrepitates, but is infusible, *per se*. With borax it melts into a green glass. Its constituent parts, according to Klaproth, are

58	Copper
18	Oxygen
12.5	Carbonic acid
11.5	Water
<hr/>	
100	

It occurs usually in the newer primitive and floetz mountains, accompanied by other ores of copper, also by carbonate of lead, calcareous spar, brown spar, and quartz. The finest specimens of this variety of malachite are found in the Siberian and Hungarian mines; it occurs also in Saxony and other mining districts in Germany, in Norway, and in Shetland, and the counties of Cornwall and Derby in Britain.

Var. 2. Compact.

Its colour is emerald-green passing into grass and verdegris-green, the same specimen exhibiting different shades of colour: its external surface is commonly overspread with a greenish-white crust. It occurs massive and disseminated, but most frequently reniform, botryoidal, mamillated, stalactitic, or globular. Externally it is rough and dull; inter-

nally it is, according to the fracture, either dull, glistening, or shining. Its fracture is conchoidal, or fine-granular uneven, or minutely fibrous. It generally occurs in thin lamellar concentric distinct concretions, each of which has usually a different shade of colour. It is opaque, soft, brittle, and easily frangible. Sp. gr. 3.5.—3.6.

Its chemical characters and component parts are nearly the same as those of the preceding variety, with which it also agrees in its geognostic and geographical situation.

Its beautiful colour, lustre, and the high polish that it is capable of receiving, render it much sought after for various ornamental purposes: it would however be much more esteemed if it was harder.

Sp. 12. Mountain-green. *Kuppergrün. Vert de cuivre.*

Its colour is verdegris-green, passing occasionally into emerald-green and sky-blue. It occurs in mass, disseminated or inverting. Internally it is shining passing into glittering, with a resinous lustre. Its fracture is small conchoidal. It is translucent and semi-transparent; is soft and easily frangible.

Its chief chemical character is that of giving little or no effervescence, while dissolving in acids. It has not been analyzed. It is found in similar situations with malachite, but is of much rarer occurrence.

Sp. 13. Emerald copper. *Kupperfchmaragd. Diopside of Haüy.*

Its colour is emerald-green. It occurs crystallized in lengthened dodecahedrons. It is shining both externally and internally, and has a vitreous lustre. It is translucent, passing to semi-transparent; scratches glass feebly, and with difficulty; is brittle. Sp. gr. 3.3.

Before the blow-pipe it becomes of a chestnut-brown colour, and is infusible, *per se*. With borax it gives a bead of copper. According to an analysis by Vauquelin it consists of

25.57	Oxyd of copper
42.85	Carbonat of lime
28.57	Silex
<hr/>	
96.99	

It has hitherto been found only in Daouria on the Russian and Chinese frontiers in a vein accompanied by malachite.

Sp. 14. Micaceous copper. *Kupperglimmer.*

Its colour is deep emerald-green passing to verdegris-green. It occurs massive, disseminated, and crystallized in hexahedral tables. Externally it is smooth and shining with a pearly lustre. Its fracture is foliated. It is translucent passing into semi-transparent. It is softer than calcareous spar. Sp. gr. 2.54.

It decrepitates strongly when suddenly heated, and is composed, according to Chenevix, of

58	Oxyd of copper
21	Arsenic acid
21	Water
<hr/>	
100	

It is found in Huel Gorland mine in Cornwall, in veins accompanied by vitreous copper, copper pyrites, arsenical pyrites, and iron ochre.

Sp. 15. Octohedral arseniat of copper. *Linsenerz* of Werner.

Its colour is deep sky-blue, passing into Prussian-blue, blueish-white, apple-green, and grass-green. It occurs in obtuse pyramidal octohedrons. The crystals are small and aggregated into clusters; they have a shining vitreous lustre,

and a lamellar fracture, are semi-transparent passing into transparent. In hardness they are inferior to fluor spar. Sp. gr. 2.88.

It is composed, according to Chenevix, of

49	Oxyd of copper
14	Arsenic acid
35	Water
<hr/>	
98	

It is found in the same mine as the preceding species.

Sp. 16. Foliated arseniat of copper. *Blattriges olivenerz* of Werner.

Its colour is olive-green, passing to oil and leek-green. It occurs rarely massive, and generally crystallized in acute rhomboids and oblique quadrilateral prisms. The surfaces of the crystals are smooth and shining. Internally it is glistening and shining, with a diamond lustre. Its fracture is imperfectly foliated. It is translucent passing into transparent. It is somewhat harder than calcareous spar. Its component parts, according to Chenevix, are,

54	Oxyd of copper
30	Arsenic acid
16	Water
<hr/>	
100	

It is found in the same mine with Sp. 14.

Sp. 17. Fibrous arseniat of copper. *Fasfriges olivenerz*. Werner.

Its colour is brownish, or dark bottle green, passing into yellowish; when capillary it is of a lighter and brighter colour. It occurs crystallized in an irregular acute octohedron, or a long compressed hexahedral prism, or capillary. Sometimes the crystals are regular at one extremity, and terminate in capillary brushes at the other. The crystals are small and laterally aggregated. It has a considerable lustre between vitreous and resinous, is translucent passing to transparent; is harder than fluor spar, but will not scratch glass. Sp. gr. 4.28. It passes into the two following varieties.

1. Amiaethiform.

Its colour varies from blueish-green to grass-green, brown-green, straw-yellow, and white. It occurs in extremely minute parallel, or diverging flexible fibres, or thin dusty flexible laminae, with more or less of a fatty lustre.

2. Hæmatitiform.

Its colour is brownish or whitish-yellow. It occurs in flat or mamillated layers, either smooth or varied with small rough crystalline points.

Its texture is fibrous but very compact, resembling wood-tin.

The above species, with its varieties, has been analyzed by Mr. Chenevix, with the following result:

Prismatic. Capillary. Hæmatif.

65.	51.	50.	Oxyd of copper
39.7	29.	29.	Arsenic acid
0.	18.	21.	Water
<hr/>			
99.7	98.	100.	

It is found in Huel Gorland mine, in Cornwall.

Sp. 18. Phosphat of copper.

Its colour is, externally, greyish-black; internally, between emerald and verdagris-green. It occurs in mass, disseminated and crystallized in rhomboids. The crystals are small and very small; their lustre is externally vitreous

and shining. Internally, it is glistening with a silky lustre. Its fracture is fine and diverging fibrous. It is opaque, and moderately hard. It consists, according to Klaproth, of

68.13	Oxyd of copper
30.95	Phosphoric acid
<hr/>	
99.08	

It has hitherto been found only at Firneberg in Cologne, in white drusy quartz.

Sp. 19. Sandy copper. *Salzkuppererz*. Werner.

Its colour is emerald-green, passing into leek and olive-green. It occurs massive, disseminated, and crystallized in extremely minute six or four-sided prisms. The surface of the crystals is smooth and brilliant, and their fracture lamellar. The massive variety is opaque; the crystals are transparent. It is soft and easily frangible. Sp. gr. 4.43.

Before the blow-pipe on charcoal, it tinges the flame of a bright green and blue colour, and a metallic globule remains behind. It is soluble in nitrous acid, without effervescence. The following are its constituent parts, according to Proust and Klaproth.

Proust.		Klaproth.
From Peru.	Chili.	Chili.
76.595	70.482	73. Oxyd of copper
10.638	11.446	10.1 Muriatic acid
12.767	18.072	16.9 Water
<hr/>	<hr/>	<hr/>
100.	100.	100.

It is found loose in the bed of a river at Kernolinos, in Chili, and elsewhere, though rarely in Spanish South America.

§ 2. Assay and Analysis.

The assay of copper ores, (though by no means so accurate a method of ascertaining their metallic contents as a regular analysis) being the method by which the market price of the ore is always determined, requires the first notice. The best method, upon the whole, of conducting it, is as follows.

First, expose a small piece of the ore, under examination, to the action of the blow-pipe, and by the appearance and odour of the vapour given out, it is easy to discover whether it contains any arsenic or sulphur. It may very probably contain both, in which case, take 300 grains of the ore coarsely pulverized, mix it with half its weight of sawdust, and keep it at a moderate red heat in an earthen crucible, till the disengagement of arsenical vapour entirely ceases. Then pour the contents of the crucible into an iron mortar, and reduce them carefully to a fine powder. Transfer this powder to a test, and expose it to a good red heat, with occasional stirring, till both the charcoal and sulphur are burnt off. The residue is then to be accurately mixed with $\frac{1}{2}$ of its weight of lamp-black, half its weight of pulverized glass of borax, and a drop or two of oil; the mass thus formed, is to be put into a sound earthen crucible, a cover is to be luted on, and the whole is to be placed in a good wind furnace. The heat should be moderate for the first quarter of an hour, to allow the borax time to combine with the earthy impurities of the ore; then a moderate white heat is to be applied for about twenty minutes. After this, the crucible being withdrawn and cooled, is to be care-

fully broken, and will be found to contain a button of copper, covered by vitreous scoria. The purity of the copper thus procured, is to be estimated from its colour, softness, malleability, and tenacity; after which, a part of it may be cupelled with pure lead, in order to ascertain whether it holds any silver or gold. If the ore contains sulphur, but no arsenic, it may be mixed with half its weight of charcoal, and roasted on a test, without being previously heated in the crucible. If the ore contains neither sulphur nor arsenic, it should be first moderately ignited in a covered crucible, to drive off any moisture, and may then be treated with borax and lamp black, as already described.

The proper analysis, by means of liquid menstrua, is however much more accurate than even the most carefully conducted assay, and the general mode of proceeding with the ores of copper is, upon the whole, very simple. The copper, together with the other metals with which it may happen to be mixed, is to be separated from the filix and sulphur, by means of an acid, the other metals are then to be got rid of by their appropriate reagents, and the copper is then to be procured either in the state of green carbonat, of black oxyd, or of pure metal; of the first, 180 parts are equivalent to 100 of metallic copper; and of the second, 100 parts contain 80 of metal.

Previously to undertaking an analysis, a part of the specimen, under examination, should be subjected to the usual reagents, in order to ascertain not indeed the proportion, but the nature of the ingredients of which it consists; and, in few cases is this more necessary than in the analysis of the ores of copper, both as they are so numerous and so various in their composition. This previous examination being duly performed, the analysis may be conducted in the following manner:

For the analysis of the *pyritical*, and other *sulphurized* ores of copper, provided they contain neither silver nor lead, take 200 grains of the pulverized ore, and digest it at a boiling heat with muriatic acid, (adding occasionally a few drops of nitric acid) till every thing soluble in this menstruum is taken up. Of the insoluble portion, a part, consisting chiefly of sulphur, will be found floating on the liquor; and this being washed, dried, and weighed, is to be ignited on a test, by which the sulphur will be burnt off, and its amount may be estimated from the loss of weight sustained by the process. The incombustible residue is to be digested in a little warm muriatic acid, and what remains insoluble, is to be added to the other insoluble residue. The muriatic solutions being mixed together, the whole is to be decomposed by carbonated potash, and the precipitate, hence resulting, is to be digested in repeated portions of caustic ammonia, as long as this latter acquires any blue tinge. The whole of the copper, and nothing else, will thus be taken up by the ammonia, from which it may be obtained in the state of black oxyd, by the addition of a little caustic potash, and a boiling heat. The residue, insoluble in ammonia, consists of oxyd of iron, with perhaps a little alumine, which may be separated by caustic potash, the alumine alone being soluble in this fluid. Finally, the portion insoluble in muriatic acid, may be considered as little else than filix.

The ores which, besides copper, sulphur, and iron, contain silver, lead, and antimony, may be thus analyzed. The ore, reduced to fine powder, is to be repeatedly digested with moderately diluted nitric acid, as long as any thing continues to be taken up by this menstruum. To the nitric solution is then to be added muriat of soda, which will throw down

the silver in the state of luna cornea; this being separated, the lead is to be precipitated in the form of sulphat, by sulphat of soda; the solution is now to be supersaturated with ammonia, which will dissolve the copper, and leave behind the oxyd of iron, with probably a little alumine and filix. The copper is to be procured from the ammoniacal solution, in the manner directed in the preceding paragraph; and the oxyd of iron may be separated from the admixed earths, by caustic potash. That portion of ore, insoluble in nitric acid, is to be digested in muriatic acid, which will take up every thing except the sulphur, filix, and probably a little luna cornea. Of this insoluble residue, the sulphur is to be burnt off by gentle ignition, and the remainder is to be fused with twice its weight of pearlash, by which the silver in the luna cornea will be reduced to the metallic state. The muriatic solution being concentrated by evaporation, and then poured into a considerable quantity of water, will deposit the antimony in the form of a white oxyd.

The simple oxyds of copper, are best analyzed by digestion in nitric acid, and then supersaturating the solution with ammonia, by which any casual admixture of iron will be separated.

The carbonats of copper are to be thus treated. One portion is to be gently calcined in a covered crucible, and the loss of weight sustained, indicates the united amount of the water and carbonic acid. A second portion is to be thrown into a known quantity of dilute sulphuric acid, and the loss of weight, by the effervescence which ensues, shows the amount of carbonic acid. The sulphat of copper thus obtained, may be subsequently decomposed, either by a stick of zinc, or by liquid ammonia.

The arseniats of copper are most conveniently analyzed by first moderately heating them, in order to drive off and thus estimate the water, and then digesting the residue in dilute nitric acid, by which it will be entirely dissolved; nitrat of lead is then to be dropped in as long as it occasions any precipitate, and this latter being removed, the fluid is to be evaporated nearly to dryness, after which, warm alcohol is to be added, which will take up the whole, except a white powder; this powder, and the precipitate on the addition of nitrated lead, are arseniat of lead, 33.66 per cent. of which is arsenic acid. The alcoholic solution is then to be evaporated nearly to dryness, and then to be digested with ammonia, which will take up the copper, leaving behind any oxyd of iron that may have happened to be contained in the ore. The ammoniuret of copper, being decomposed by caustic potash, gives the copper in the state of black oxyd, which is that in which it exists in the ore.

The analysis of *muriat of copper* is very simple. It was thus effected by Klaproth. The ore, being pulverized, was dissolved in cold nitric acid, with the exception of 1.5 per cent. of oxyd of iron; the solution being then diluted, nitrat of silver was added, till it occasioned no further precipitate; the luna cornea thus obtained, indicated, according to the known proportions of this salt, the amount of muriatic acid in the ore. The nitrous solution was then decomposed, and the copper obtained in the metallic form, by means of a bar of iron.

Phosphat of copper was thus analyzed by Klaproth. On digestion in nitric acid, the whole was taken up except a few grains of quartz; the excess of acid in the solution was then saturated by potash, and acetite of lead was poured in till it had quite ceased to occasion any precipitate; the phosphat of lead, thus obtained, was separated from the solution, and sulphat of soda was added to decompose and

precipitate the small excess of acetite of lead which had been made use of. A little sulphuric acid was then added to the solution, and the copper was precipitated in the usual way, by means of a bar of iron.

§ 3. *Reduction of Ores.*

The only ores of copper that are in fact wrought in the large way, and from which the copper of commerce is for the most part supplied, are the sulphureous and arsenical ores of this metal. The method of reducing them, though consisting of a great number of processes, on account of the powerful affinity, both of the arsenic and sulphur, is yet upon the whole very simple, being little more than repeated roastings and fusions, till the metal has acquired the necessary ductility, for it is never brought to a state of absolute purity, and the commoner sorts contain both arsenic and antimony, in such proportions, as to be wholly unfit for alloying with either gold or silver.

The rough ore, if simply sulphureous, is broken into pieces not larger than an egg, and separated as much as possible from the adhering earthy impurities; after which, it is piled in large kilns, and heat being applied at the bottom, the whole mass becomes gradually heated, and a large portion of the sulphur sublimes out, and may be either collected by proper flues, or allowed to escape; this first process occupies about six months, at the expiration of which time, the evaporation of the sulphur ceases, and when the ore has cooled sufficiently, it is in a fit state to be smelted.

If, however, the ore is largely combined with arsenic, it is not capable of keeping up a long combustion of itself, nor is the heat thus generated adequate to the expulsion of the arsenic; a somewhat different method, therefore, of roasting must be had recourse to. For this purpose the ore is still more carefully dressed than in the former case, and is reduced to pieces not larger than a hazle-nut. It is then spread on the floor of a large reverberatory furnace, and exposed to a dull red heat, with frequent stirring, in order to offer fresh surfaces to the action of the flame. The arsenic and sulphur by this treatment are rapidly driven off, and in about twelve hours the roasting is completed.

The ore is now transferred into the fusing furnace, which is a reverberatory of the common construction; a little bruised lime-stone is generally added by way of flux, and in the course of four or five hours the fusion is usually complete; the slag, now of the consistence of soft dough, is raked off, and the copper is discharged through a plug-hole into water, by which it is reduced into small drops or grains.

The copper, however, though in the metallic state, is still very impure, being largely mixed with sulphur and arsenic, which give it a grey colour, and render it perfectly brittle. In order to separate these impurities, it is re-melted and granulated twice more or oftener, a considerable quantity of slag being separated at each fusion; but as this slag contains some copper it is not thrown away, but worked over again with the next charge of calcined ore. The number of fusions and granulations entirely depend on the quantity of impurities, and the obstinacy with which they combine with the copper; but when these processes have been repeated the requisite number of times, the granulated mass is melted and cast into pigs. These again are broken to pieces, and roasted for one or two days in a low red heat, and again melted and roasted several times, till the metal approaches to the state of malleable copper. It is now cast into oblong masses, about 14 inches in length, and is fit for the refining furnace. In this it is again melted, with the addition of a

little charcoal, till it acquires the necessary degree of malleability, and thus becomes saleable copper.

Sometimes lead is employed with good effect in the refining of copper, as it combines with, and scorifies iron, and the other easily oxydable metals in preference to copper. For this purpose the rough copper is spread on the floor of a furnace, and when it is in complete fusion, about 6 or 8 *per cent.* of lead is thrown in, and well mixed with the rest. In a short time the surface of the melted metal becomes covered with a semi-vitreous blackish brown scoria, consisting of the mixed oxyds of lead, iron, and other impurities, together with a little copper. The first scoria being removed, a second is formed, which is in like manner skimmed off, and so on successively, till, after ten or twelve hours, the copper is sufficiently purified: this is ascertained by the thinness of the film with which the melted copper is covered, and by its being of a brick-red colour, also by the circumstance that if a rod of polished iron is dipped into the fused mass the portion of copper that adheres to it immediately falls off when the rod is dipped in cold water.

§ 4. *Chemical and Physical Properties.*

The colour of copper is yellowish-red; its hardness is superior to that of silver, but somewhat inferior to that of platinum; it is very tough, ductile, and malleable; hence it may be beaten into plates or drawn into wire of great strength and compactness. It breaks with a hackly fracture. When rubbed, it emits a disagreeable odour; to the taste it is nauseous and styptic. The specific gravity of Swedish copper, which is the purest that is met with in commerce, amounts to about 8.89: that of the commoner sorts does not exceed 8.6; while that of the Japanese copper, on the other hand, amounts, according to Bergmann, to 9.0.

The fusing point of copper is nearly the same as that of gold, namely, a low white heat; before it melts, changeable prismatic colours appear on its surface. When in fusion, or even at a full red heat, if exposed to the air, it is soon covered with a thin brittle plate of brownish oxyd, that readily separates from the metal when cold.

This substance is an imperfect oxyd, and was formerly called *copper ashes*, *as ustum*, or *cinis aris*, and by repeatedly heating and cooling a bar of this metal, the whole may be thus changed. These scales, according to Proust, are composed of about 62 *per cent.* of perfect or black oxyd, and 38 of copper nearly in the metallic state; hence, when they are digested in cold dilute sulphuric acid, only the former portion is taken up. By subsequent calcination, the scales are wholly converted into black oxyd, the weight of which is one-fourth more than that of the original copper. At a very high heat, this oxyd runs into a bright reddish-brown opaque glass.

Copper, when in high fusion, and in contact with the air, like all the other easily oxydable metals, is actually combustible; it burns with a beautiful light green flame; the same delicate tinge is visible when a little of the oxyd, or of any of the salts of this metal, is strewed on burning coals. The green flame thus produced deposits a small portion of greenish-grey pulverulent oxyd, and hence it gradually collects as a kind of soot in the chimnies of furnaces employed in smelting this metal.

Copper soon rusts in a damp air, and becomes covered with a green crust of carbonated oxyd, but this coating, by its strong adhesion to the metal beneath, long preserves it from further alteration; hence it requires a length of time, and the concurrence of circumstances peculiarly unfavourable to preservation, in order to corrode entirely a thick plate of

this metal. Water is not decomposed by copper even at a white heat.

With the exception of a few cases, that will be mentioned presently, copper appears to unite very uniformly with the same proportion of oxygen, forming (when uncombined with water and every other substance) a brownish-black oxyd, of which one-fifth, or 20 *per cent.*, is oxygen, and the remainder copper. This oxyd is produced, as has been already mentioned, by boiling the precipitate from any of the cupreous salts by an alkali, or the ammoniuret of copper, with caustic potash or soda.

Copper, or rather its oxyd, combines with every acid, forming salts, many of which are both curious and important.

Sulphuric acid acts upon metallic copper only when concentrated and boiling hot. For this purpose take copper filings, or thin sheet copper, put it into a glass vessel with twice its weight of strong sulphuric acid, and heat the mixture. As soon as it begins to boil, much sulphureous acid gas is given out, and at length the whole dissolves into a dark-coloured liquor, which, by dilution with water, becomes of a fine blue. If common copper is used for this purpose, there always remains a black sediment, which consists for the most part of sulphuret of copper. If the pure carbonated oxyds are employed, instead of the metal, they will be found to be soluble even in cold and diluted sulphuric acid. The solution, in whichever way it is formed, deposits, by evaporation and gradual cooling, rhomboidal crystals of a deep sky-blue colour, which are sulphat of copper, the *blue* or *Roman vitriol* of the shops.

The same salt is also met with native in copper mines, partly crystallized, but more generally dissolved in the water which drains more or less into all mines. When native, it appears to be formed in consequence of the iron pyrites being first vitriolized, and the resulting sulphat of iron re-acting on the copper.

Sulphat of copper has a very strong, styptic, somewhat acidulous, and excessively nauseous taste. It is soluble in about four times its weight of water. When dried at a heat not exceeding that of boiling water, it loses, according to Proust, about 36 *per cent.*, which is mere water, after which the residue, which is a white pulverulent mass, is again soluble and crystallizable, as at first. But if it is calcined with a strong white heat, the acid itself is expelled without undergoing decomposition, and at length there only remains black oxyd of copper, in the proportion of 32 *per cent.* of the original crystallized salt. Hence 100 parts of sulphat of copper consist, according to Proust, of

Copper 25.6	} forming	} 32
Oxygen 6.4		
	Sulphuric acid	32
	Water	36
		<hr/>
		100

Bergmann's analysis of this salt nearly agrees with that of Proust in the proportion of copper (26 *per cent.*); but of the other ingredients he reckons 28 of water, and 46 of acid.

Besides the common sulphat, Proust describes a *sub-sulphat* of copper. This is prepared by adding to the common sulphat some caustic potash, but not sufficient entirely to decompose it. A green precipitate is in consequence deposited, which is the sub-sulphat in question. This salt loses by distillation only 14 *per cent.* of water. The residue, boiled

with caustic potash, gives 68 *per cent.* of black oxyd; hence its component parts are

Copper 54.4	} 68
Oxygen 13.6	
Sulphuric acid	18
Water	14
	<hr/>
	100

Sulphat of copper is decomposed by the alkalies, whether pure or carbonated. If either of the fixed alkalies in their caustic state is made use of, the precipitate is not, as might be supposed, a simple oxyd of copper, but that peculiar combination first discovered by Proust, and named by him *hydrat of copper*. It is thus prepared: to a cold solution of sulphat of copper add liquid potash, also cold, to complete saturation; a *blue* precipitate falls down, which, when thoroughly washed with boiling water, is the pure hydrat. Its consistence, when dried at a heat not exceeding 212° Fahr., is nearly that of Prussian-blue; at a somewhat higher temperature it shrinks, and is gradually converted into black oxyd, by the evaporation of its water. By dry distillation it is found to give out about 24 *per cent.* of water, and 1 of carbonic acid, which it probably has absorbed from the air while drying: there remain behind 75 parts of black oxyd. If this latter is again moistened with water, it does not return to the state of hydrat. Hence it appears that the hydrat is a true chemical combination of water and oxyd of copper, in the proportion of about one part of the former to three of the latter, and as such enters into the composition of the cupreous salts. The hydrat is decomposable not merely by heat, but also by *boiling* with either of the fixed alkalies.

Carbonic acid and oxyd of copper unite together without difficulty. This combination is found native, forming the mountain-blue, the malachite, and some of the other ores of copper. It may be prepared artificially by exposing the metal to a damp confined air, in which case it constitutes rust of copper; or more expeditiously by decomposing any of the acid salts of copper by a carbonated alkali. A copious bulky precipitate falls down, which, when well washed and gently dried, is a fine powder, of a beautiful pale apple-green colour. One hundred parts of copper dissolved in any acid, and precipitated by carbonated potash or soda, produce invariably 180 of the green carbonat, dried at a boiling-water heat. This carbonat, when distilled by itself, with a heat gradually increased to redness, gives out 10 parts of water, and 46 of carbonic acid; the black oxyd, remaining behind in the retort, amounts to 125 parts, of which 100 are copper, and 25 oxygen.

When hydrat of copper is gently heated with a solution of super-carbonated potash, a portion is dissolved, forming a greenish-blue liquor, whilst the undissolved residue becomes almost as dark in colour as the black oxyd. The solution, if slowly evaporated, yields a singular salt, consisting of 52 *per cent.* potash, 43 carbonic acid, and 5 oxyd of copper. It is crystallizable and slightly deliquescent. A similar salt, with a base of soda, is produced, when this latter alkali is employed instead of potash.

Copper is very readily soluble in nitric acid, even when cold and considerably diluted. Much heat is excited, and a torrent of nitrous gas given out, the liquor becoming of a bright blue colour in proportion as the copper is dissolved. The oxyds of copper are equally soluble in this acid as the metal is, but without the evolution of nitrous gas. When this solution is hastily evaporated to a certain point,

and then suffered to cool, it congeals into a deep blue saline mass, which deliquesces rapidly when exposed to the air. By a slow and careful evaporation this salt may be obtained in the form of hexahedral prisms, but equally deliquescent as the former amorphous variety. If this blue nitrat be evaporated beyond the point at which it would crystallize when cold, nitrous gas begins to be produced, and a green scaly concretion separates from the thick blue liquor. If the evaporation is here stopped, this green matter may be separated by water, either hot or cold, which dissolves only the undecomposed blue nitrat. This green substance is considered by Proust as a subnitrat of copper; that it still contains nitric acid is proved by its still giving out this acid when mixed with sulphuric acid and heated. By thorough calcination all the acid and water are expelled, and the black oxyd of copper only remains. The proportions of the subnitrat, according to the above-mentioned chemist, are

Black oxyd of copper	67
Nitric acid - -	16
Water - - -	17

The blue or perfect nitrat, on the other hand, contains only 27 per cent. of black oxyd.

Nitrat of copper is very soluble in alcohol, to the flame of which it communicates a very delicate green colour.

The decomposition of this nitrat by tin is so violent as in certain cases to produce actual combustion. This forms an amusing experiment, and was, we believe, first discovered by Dr. Higgins. It is thus performed; spread out a piece of tin-foil four or five inches square, lay in the middle a small heap of the solid blue nitrat, sprinkle the salt with a few drops of water, spread over it a little tow, then double up the tin-foil round it on all sides, twisting it as tight as may be without breaking. In a short time the mass will feel burning hot, small bubbles of blue liquor will be seen oozing through, and will presently be succeeded by a copious eruption of nitrous gas, attended by minute sparks of fire and deflagration.

A fine blue pigment is prepared from nitrated copper, called *verditer* (*cendres bleues*, Fr.) It is made in quantity by the refiners, who, after the process of separating silver from gold by aquafortis, recover the silver from its solution by means of copper, and thus obtain a residue of nitrat of copper. This solution is decomposed by lime (the precise method of doing which is kept secret), and the produce being made into cakes and dried slowly constitutes the best kind of verditer.

This pigment has been analyzed by Pelletier with the following results. It was totally soluble in nitric and muriatic acids, with a copious effervescence of carbonic acid: when distilled by itself 600 hundred grains lost 200, and afforded 2 French pints of carbonic acid together with some water. The calcined residue was a black powder, which, being fused with a reducing flux, yielded a button of pure copper, amounting to about half the weight of the original verditer. A fresh parcel was then treated with sulphuric acid, which afforded sulphat of lime, the earth of which formed about 7 per cent. of the original verditer. Of the 200 grains lost by distillation, Pelletier considers 180 as carbonic acid. Hence 100 parts of verditer contain

Copper	
Carbonic acid	
Water -	
Lime -	

Remains for oxygen

100

But in this estimate the amount of carbonic acid is by some oversight greatly overrated. The quantity obtained from 600 grains was about 2 French pints, the weight of which, according to Lavoisier, would be only 66 grains; consequently 100 grains would yield only 11 grains of this acid. The water was obviously only estimated at random, and as the copper was in the state of hydrat, certainly amounted to much more than Pelletier has allowed for it. The corrected results of the above analysis therefore would be

Copper	50	} 83.3 Hydrat of copper
Oxygen	12.5	
Water	20.8	
Lime	7.	
Carbonic acid	11.	
		<hr/>
		101.3

which corresponds very closely with the quantity analyzed.

The muriatic acid dissolves copper with difficulty except when concentrated and boiling, and then hydrogen gas is given out. The oxyds, however, of this metal, and especially the green carbonat, are very readily soluble in this acid. The colour of muriat of copper when hot or highly concentrated is brown, but by dilution becomes of a grass-green. By careful evaporation and cooling it crystallizes in lengthened rhomboids, and when hastily evaporated in feathery crystals. This salt is commonly deliquescent, but when both the copper and acid are quite free from iron is permanent in the air. It is readily soluble both in water and alcohol; the latter takes up its own weight when boiling, a part of which afterwards separates in a crystalline state as the liquor cools. The composition of the crystallized salt is, according to Proust,

Black oxyd of copper	40
Muriatic acid	- 24
Water	- - 36
	<hr/>
	100

A dilute solution of muriated copper in water makes a kind of sympathetic ink, which is colourless in the cold, becomes yellow by warming, and again loses its colour on cooling. Besides the common muriat, the ingenious researches of Proust have discovered a second muriat, in which the copper appears to be at a lower state of oxydation than in the former salt. It affords a nearly colourless solution, and when solid is of a greyish white; it may therefore without impropriety be called the white muriat of copper. It is prepared from the common muriat by means of muriat of tin, a salt remarkable for the eagerness with which it absorbs oxygen from almost all the other metallic salts. If therefore some of this latter is poured into common muriat of copper, a precipitate falls down which is at first white, but by subsequent exposure to air passes

through different shades of violet and blue to black. This precipitate is for the most part a muriated sub-oxyl of copper. On exposure to a moderate heat it melts like luna cornea. If digested in warm muriatic acid it readily dissolves, and is deposited, on cooling, in the form of tetrahedral crystals. With nitrous acid some nitrous gas is given out, which shews that the metal was not previously saturated with oxygen. Another remarkable character of this white muriat is, that when dissolved in ammonia the solution is colourless, though, on exposure to the air, it gradually acquires the sky-blue colour of common ammoniac of copper. Its composition, according to Proust, is

Muriatic acid	24.75
Oxyl of tin	1.
Copper	- 63.
Oxygen	- 11.25

Assuming this analysis as correct, it is obvious that the copper exists in a much lower state of oxygenation in this salt than in any hitherto mentioned, for in this the oxyl of copper is composed of 63 of metal and 11.25 of oxygen, or (reduced to the hundred) of 84.84 copper, and 15.16 oxygen, whereas the black copper, to which all the common cupreous salts are reducible by loss of their acid and water, consists of 80 *per cent.* copper, and 20 oxygen.

There appears to be yet another state of combination of muriatic acid and oxyl of copper, also first noticed by Proust. It is the *submuriat of copper*, differing from the common muriat not by a lower degree of oxygenation in the metal, but in a smaller proportion of acid. It is produced by adding a little potash (less than required for saturation) to the green muriat. A green powder falls down, which is the submuriat in question. This salt when boiled with potash loses about 28 *per cent.* of its weight, and is reduced to the black oxyl. A similar submuriat is said by the same chemist to be spontaneously deposited when copper is dissolved in nitro-muriatic acid. The composition of this salt is as follows:

Black oxyl of copper	
Muriatic acid	-
Water	-

100.

The native green muriat of copper from Peru appears to be nearly in this state.

Copper seems to have a stronger affinity for muriatic acid than even for the nitric or sulphuric. Thus, if either the solid nitrat or sulphat of copper be digested in muriatic acid a solution takes place, and then, on the application of heat, the liquor immediately loses the blue colour, characteristic of these two salts, and acquires the green of the muriat: also by slow evaporation muriat of copper is obtained in crystals.

Acetous acid has no action on reguline copper, but its oxyl is easily soluble in this fluid, to which it communicates a beautiful grass-green colour. There are two species of acetited copper, the one with an excess of base, the common verdegriis of the shops, and the other in which the acid and oxyl are in a state of mutual saturation, forming the crystallized or distilled verdegriis.

The manufacture of verdegriis is carried on to a considerable extent in most of the southern provinces of France,

and a very exact account, apparently, of the process has been published by Chaptal, from which the following particulars are extracted.

The materials for this manufacture are the *marc* or cake that remains in the wine-press, after the greater part of the juice has been squeezed out; and plates of copper of convenient size and hammered well, in order to smooth the surface, that the corroded portion may be readily detached from the rest.

The marc of the grape is first fermented by being laid as lightly as possible in a large barrel and moistened with common wine, and then set in a warm airy place. In a few days, varying according to the heat of the weather, it begins to swell, grows hot and exhales a strong odour of vinegar; the fermentation then declines and the marc is fit for use. A layer of this is then put into an earthen pot and a plate of copper, previously made scorching hot, is laid upon it; to this succeeds another layer of marc, and then a plate of copper, in regular alternation till the pot is filled, observing that both the top and bottom layers are of marc. The mouth of the pot is then loosely stopped with straw, and the whole is left at rest from ten to twenty days.

When the marc begins to whiten the pots are unpacked, and, if the process has gone on well, the copper-plates are found covered with a green crust, interspersed with silky green crystals. The marc is thrown away; the plates are let on end on wooden racks in a cellar, and when dry are dipped in water and again set to dry; this is repeated once a week for six or eight times, which makes the crust of oxyl swell and increase both in quantity and quality: after which it is scraped off by a knife without difficulty. Each pot yields about 5 or 6 lbs. of rough verdegriis, and the plates will serve again repeatedly till they are corroded quite through.

This rough verdegriis is further prepared for market by being ground in wooden mortars, and exposed to the air till it is sufficiently dry; and in so doing it loses about half its weight.

Verdegriis thus prepared, may be considered as copper oxydated by the action of the acetous acid, and combined with water, with carbonic acid, and with part of the extractive or mucilaginous part of the marc. It is nearly insoluble in water and its colour is blueish green. If this verdegriis is digested in distilled vinegar it dissolves readily in this fluid, and by evaporation and cooling a crystallized salt of a deep green colour may be obtained, which is known in the shops by the name of *distilled verdegriis*. The method in which this valuable salt is prepared at Montpellier is as follows. Common vinegar is first distilled in a copper alembic, and the acid thus produced is put with common verdegriis into a copper boiler; when a hot saturated solution is thus made, it is strained and transferred to another copper evaporating vessel, where it is boiled down till a saline crust begins to collect on its surface; a light frame of cross sticks is now sunk into the liquor and the fire is put out. On cooling, the acetite of copper crusts round the sticks in clusters of rhomboidal crystals of a deep blueish-green colour. It requires about 3 lbs. of verdegriis to make 1 lb. of the crystallized acetite.

The composition of common verdegriis is subject (as might be expected from the method in which it is prepared) to a considerable variation, and this difference is still further increased by variations in the way of manufacturing this salt. Thus, at Grenoble, verdegriis is made merely by dissolving plates of copper in a proper room, and moistening their

surfaces repeatedly with distilled vinegar, till the incrustation of oxyd acquires a proper thickness. Hence this latter is purer, and approaches nearer to the state of crystallized acetite, than that of Montpellier.

A hundred parts of the verdegriis of Grenoble yield, according to Chaptal, by dry distillation,

Carbonic acid	-	-	9.1
Water weakly acidulous	-	-	13.05
Strong, and coloured acetous acid	-	-	13.95
Left in the retort	Copper	-	20.9
	Charcoal	-	3.
			100.

A like quantity of the Montpellier verdegriis afforded

Carbonic acid	-	-	8.
Acetous acid, weak and empyreumatic,	-	-	-
Copper	-	-	-
Charcoal	-	-	-
			100.

To the above particulars may be added some observations, by Proust, on the properties and composition of this salt.

When common verdegriis is put into cold water, it gradually falls to pieces and nearly half of it is dissolved, the remainder is a fine green powder which diffuses itself through the liquor and subsides very slowly. This green powder appears to be pure subacetite of copper, and when washed and dried weighs about 42 *per cent.* of the original verdegriis. When sulphuric acid is poured on it, pungent vapours of vinegar are given out. Boiled with potash it affords 63 *per cent.* of black oxyd; and when distilled, after all the volatile products have passed over, there remains about 52 *per cent.* of copper, principally in the metallic state. From these data therefore the subacetite appears to consist of

Copper	50.4	} forming black oxyd	63
Oxygen	12.6		
Remains for acid and water			37
			100

With regard to the crystallized acetite, Proust found that 39 parts of black oxyd produce, with distilled vinegar, 100 parts of acetite; and on the other hand, that 100 parts of this salt, when decomposed by boiling with potash, yield 39 or 40 parts of black oxyd. Hence it is composed of

Copper	31.2	} forming black oxyd	39
Oxygen	7.8		
Acetous acid	-	-	61
			100

The distillation of the crystallized acetite furnishes the most pungent acetic acid, or radical vinegar, as has been already described under ACETOUS ACIDS. Acetite of copper, beside being made by direct combination of its ingredients, may be prepared in various ways by double affinity; of these the best upon the whole is the following: Make a cold solution of sugar of lead (*acetite of lead*) in distilled water, to which add, by degrees, a cold solution of blue vitriol (*sulphat of copper*), as long as any precipitation takes place; then pour the whole on a filter, and a green liquor passes through, the sulphat of lead remaining on the filter, in the form of a white powder. The green liquor, being concen-

trated by evaporation, deposits, by cooling, very pure and beautiful crystals of acetite of copper.

The natural combinations of copper with arsenic and arsenic acid have already been noticed. With regard to the artificial arseniats, Scheele discovered that when arsenic acid is digested with copper filings, a green solution is formed, and a blue powder, which is also an arseniat, is precipitated. The sulphat, nitrat, and muriat of copper undergo no apparent change, when added to arsenic acid; but the acetite is decomposed, and arseniat of copper is precipitated. All the cupreous salts, however, are decomposed by arseniated alkali, and a blue arseniat falls down. To these facts Mr. Chenevix has added the following: If arseniat of ammonia and nitrat of copper are added, there falls down a blue crystalline arseniat of copper. On evaporating the supernatant liquor, and adding alcohol, another copious deposition of crystals took place, of a deeper colour than the former, and of a rhomboidal shape. Each of these arseniats was examined separately, first by calcination at a low red heat to expel the water, then by potash for the black oxyd of copper, and lastly by nitrat of lead for the arsenic acid. By this method, the first arseniat was found to consist of

Oxyd of copper	-	50
Arsenic acid	-	27
Water	-	22
		99

The second arseniat afforded

Oxyd of copper	-
Arsenic acid	-
Water	-

Arsenic, in the state of white oxyd, combines with oxyd of copper into a pale green powder, called, from its discoverer, *Scheele's green*. It is prepared in the following manner: Dissolve 24 ounces of sulphat of copper in water, and heat the solution in a copper vessel; also boil in another vessel 24 ounces of pearlsh, 11 ounces of white arsenic, and about 3 pints of water: when the whole is dissolved, strain each solution separately through linen, and then add the arsenicated potash, little by little, to the sulphat of copper, with constant stirring: an effervescence will take place, and then a green powder will be deposited. When the whole is mixed, let it stand some hours, then separate the precipitate by the filter, edulcorate it well with clear hot water, and dry it very gently in a warm room. The above quantity of ingredients will afford about 18½ ounces of the powder, which may be used as a pigment.

Phosphat of copper may be prepared by adding phosphat of soda to the nitrat, or any other readily soluble salt of copper, a blueish-green sediment falls to the bottom, which dries to a powdery semi-crystalline mass. A low red heat turns it brown, and drives off about 15.5 *per cent.* of water: there remains a phosphat of copper, composed of 35 parts of phosphoric acid, and 49.5 of oxyd of copper.

A striking decomposition of nitrat of copper also takes place, when a stick of fresh melted phosphorus is immersed in a solution of this salt, and exposed to the light. By degrees the copper is precipitated on the surface of the phosphorus, in the metallic salt, and in the form of crystalline grains.

All the salts of copper are decomposed by the alkaline prussiates, and the result is a sediment of a reddish-brown colour, which, by drying and exposure to the air, acquires a

dark chocolate hue. This prussiat of copper mixed well with oil, and has been employed with some success as a pigment.

Tincture or infusion of galls throws down from all cupreous solutions a precipitate of a dirty yellow colour.

Oxyd of copper is soluble in all the other acids, forming with them, however, salts little known, and of little importance: the predominating colour in all of them is green.

Of the alkalies, neither potash nor soda have any action on copper or its oxyds, except that already mentioned, of taking away from the hydrat its water of combination, and reducing it to black oxyd.

Ammonia has no action on metallic copper, but dissolves its oxyds without difficulty. The usual colour of this solution is a deep blue-purple. The most direct method of preparing it is by digesting together liquid ammonia and any oxyd, or carbonated oxyd of copper: the liquor becomes blue almost immediately, and its colour deepens till saturation takes place. By slow and careful evaporation, blue silky crystals of ammoniuret of copper may be procured. This salt, by exposure to the air, gradually loses its alkali, and absorbs carbonic acid, so that at length it is wholly converted into green carbonat. The *aqua sapphirina* of pharmacists and surgery consists, for the most part, of ammoniated copper, to which its colour is owing: it is made chiefly in two ways. The first is to digest in a glass vessel quick-lime, muriat of ammonia, verdegriis, and water; the lime decomposes the muriat of ammonia, disengaging the alkali, which, in its turn, decomposes the verdegriis, and dissolves the oxyd of copper: hence the clear liquor consists of ammoniated copper and muriat of lime. The second method, where a weaker solution is wanted, is to employ lime-water instead of lime. Another way of producing ammoniated copper immediately is to supersaturate with this acid any of the salts of copper, in consequence of which the first portions of alkali decompose the cupreous salt, throwing down an oxyd, and the succeeding portions redissolve the oxyd, forming a dark-blue solution. As there is no other metal besides copper and nickel which produces this particular colour, and as the latter of these metals is not common, the production of this beautiful tinge, by the addition of ammonia, may be considered as a very probable indication of the presence of copper.

A singular circumstance takes place with regard to ammoniated copper. If a bottle be filled with liquid ammonia, and a few clean copper filings be added, no solution ensues, as long as the bottle is kept close corked. But if the bottle be opened for a while, and then shut again, a solution indeed of part of the copper takes place, but without any change of colour in the liquor: but when the bottle is again opened, the characteristic blue tinge appears first at the surface of the solution, and gradually spreads down to the bottom. If now a few more copper filings be added, and the bottle again corked, the solution will in a short time again become colourless, and continue so till it is again exposed to the air. The reason of these changes appears to be the following: copper requires some, but only a very small quantity, of oxygen to be soluble in ammonia; and when in this lowest state of oxydation, it forms with ammonia a colourless solution, as it forms with muriatic acid a white sub-muriat: but if this solution is exposed to the air, the metal absorbs oxygen, and is thus brought to that state in which it tinges ammonia blue; being again shut up with a few copper filings, the oxygen is partly absorbed by the recently added metal, and reduces the whole to the state of white oxyd.

Many of the neutral salts, especially the muriats, are capable of oxydating, and, in part, of dissolving copper: this

is especially the case with muriat of ammonia, which, when made into a mass with copper filings and a little water, and kept warm, presently converts the copper into a green muriated oxyd.

Copper and sulphur readily unite. If equal parts of copper filings and flowers of sulphur are mixed and heated in a crucible, much of the sulphur burns off; but the remainder melts into a blueish-black mass, which is sulphuret of copper. According to Proust, 100 parts of copper take up in this way 28 of sulphur; so that the sulphuret is composed of about 79 of metallic copper, and 21 of sulphur. No oxygen appears to be present. This substance is more fusible than copper, melting readily at a red heat. By roasting in the open air, the sulphur is expelled: the last portions, however, adhere with great obstinacy. According to Dr. Thomson, sulphur and copper filings unite together, by being merely mixed together with or without water, and exposed for a long time to the air.

Hydrosulphureted water, or any of the liquid hydrosulphurets, when added to the solutions of copper, produce a deep blueish-black precipitate, which is a hydrosulphuret of copper.

Phosphorus is capable of intimate combination with copper. If 8 parts of this metal in filings, 8 of vitreous phosphoric acid, and 1 of charcoal powder, are intimately mixed together, and then put into a crucible, and exposed to an intense heat, the phosphoric acid is decomposed by the action of the charcoal, and the phosphorus in part burns off, and in part unites with the copper, forming a hard, steel-grey, brittle alloy, capable of a high polish. A simpler way of preparing the same is to make copper filings red hot in a crucible, and project upon them small pieces of phosphorus, which combines with the metal, and melts down into a grey mass, similar to the former. One hundred parts of copper may thus be increased to about 120; but if this phosphuret is kept for some time melted under charcoal powder, or melted glass, part of the phosphorus burns off. When this excess is thus got rid of, the ingredients of the remaining phosphuret appear to be in a state of mutual saturation, no more phosphorus being dissipated by a continuation of the fusion. In this state the mass appears to consist of 92.3 of copper, and 7.7 of phosphorus: it retains the grain and colour of steel, is susceptible of a high polish, and does not readily tarnish in the air, but is brittle. With a still less proportion of phosphorus, it becomes malleable, and of a yellowish-white colour. Phosphuret of copper, if kept in fusion, with free exposure to the air, loses gradually most of its phosphorus, which burns away with the bright flame and odour peculiar to this substance.

The fixed oils, when kept long in contact with copper, oxydate it, and dissolve a portion, by which they acquire a green colour.

The uses of copper, in its various states, are so numerous and important, as to be scarcely inferior to those of iron. All the salts of copper are more or less poisonous, producing violent nausea, with severe pain and inflammation of the intestinal canal. Yet from the sudden vomiting that they excite, a large dose may be given with safety; and this is sometimes done, when there is an immediate necessity of emptying the stomach. Copper, however, is very little used medicinally in any form.

§ 5. *Alloys of Copper.*

The alloys of copper are, upon the whole, of more importance than those of any other metal: we shall, therefore, treat of them with some minuteness.

Copper with gold and silver.

Copper, when added in small quantity to either of these metals, greatly increases their hardness, without materially debasing their colour or malleability: hence it has been generally adopted as the alloy for that portion of the precious metals which is employed with current coin, and for plate.

Copper with arsenic.

On account of the volatility of arsenic some precautions are required in the preparation of this alloy. The best way, upon the whole, is to melt some copper in rather a large crucible, and then to wrap up in paper some reguline arsenic, or white arsenic, either with or without a mixture of charcoal powder, and to immerse the paper, with its contents, in the melted copper, either by means of a pair of long tongs, or by ramming the paper into a small crucible, and then inverting the crucible in the fluid metal. The arsenic presently rises through the copper in dense white fumes, and is in a great part dissipated; a portion however is retained by the copper, and by repeating the process once or twice more, the alloy will be fully saturated with arsenic.

This alloy is of a silvery white colour and a close texture; it is however very brittle, and, in proportion to the perfect whiteness of its colour, liable to tarnish in the air. As soon as it is brought to fusion the arsenic begins to escape, and the copper regains its malleability: the last portions however of arsenic are not driven off even by long continued heat, and although the copper regains its malleability, its colour remains of a dingy yellow.

Vauquelin has discovered that if to an alloy of copper and silver, in equal proportions (the colour of which is a pale yellow), there be added 2 *per cent.* of arsenic, the result is a perfectly white ductile and malleable alloy. If this latter ingredient exceeds 5 *per cent.* the alloy begins to be brittle.

Copper with iron.

These two metals only unite when the former of them is greatly in excess. The result is a hard, grey, and somewhat brittle alloy. According to Mr. Keir, the *tutenag* of the Chinese is a white alloy of copper, zinc, and iron: it is hard, tough, and sufficiently malleable to be wrought into candlesticks and various other articles of domestic furniture, which take a high polish, and are scarcely to be distinguished from silver. The inferior sort of *tutenag* has, however, a very perceptible brassy tinge.

According to DIZÉ, the alloy of iron and copper only ceases to be acted on by the magnet, when the proportion of the former is less than $\frac{1}{8}$ of the whole mass. Iron is much inferior in its power of whitening copper to tin or even to arsenic.

Copper with lead.

These metals unite, to appearance, very intimately by fusion; but when a mass of this alloy is exposed to a very low red heat, the greater part of the lead, with a small portion of copper, sweats out, leaving the rest in a porous honey-combed state. When the copper holds a little silver, the lead carries the latter out with it: this process is called *eliquation*, and will be treated of more at large in the article SILVER. Copper, with about a fourth of its weight of lead, forms *pot-metal*. The Roman pot metal was composed, according to Pliny, of 100 parts copper, 2 lead, and 2 tin. The same ingredients, but with larger proportions of the two latter, were the materials of many of the ancient Greek and Sicilian coins, as appears from analyses of them by Klaproth.

Copper with zinc.

Copper, when nearly saturated with zinc, that is, when

the latter amounts to about one-fourth of the alloy, forms *brass*, of which an account has been already given. With a smaller proportion of zinc, the colour of the alloy approaches more nearly to that of gold, and its malleability increases. Mixtures, chiefly of these two metals, are employed to form a variety of gold coloured alloys, known by the names of *tombac*, *Manheim* or *Dutch gold*, *tinzel*, *similor*, *prince Rupert's metal*, *pinchbeck*, &c. the precise composition of which varies according to the fancy or experience of different artists. The Dutch gold may be beaten into extremely fine leaves, which when fresh are a cheap and good imitation of gold leaf; but they tarnish very soon. The mixture may be made either by melting together copper and zinc, or copper and brass. In either case the copper should be melted first, and the other ingredient added afterwards: being then carefully stirred together with a stick, the alloy is to be poured out into proper moulds without loss of time, lest the zinc should burn off.

A fine malleable tombac may be made with 16 parts of copper, one of zinc, and one of tin; if a larger proportion of this latter is added, the alloy becomes harder and brittle. Several Roman coins struck during the first century of the emperors, have been analyzed by Klaproth, and appear to consist, some of nearly pure copper, others of copper, with from a fifth to a sixth of zinc. A little tin and lead were found in some, but in such small proportions as to appear only an accidental impurity.

Copper with tin.

The alloy of copper and tin are extremely important in the arts, and curious as chemical mixtures. Tin added to copper makes it more fusible, less liable to rust or be corroded by the air and other common substances, harder, denser, and more sonorous. In these respects the alloy has a real advantage over unmixed copper; but this is in many cases more than counterbalanced by the great brittleness which even a moderate portion of tin imparts, and which is a singular circumstance, considering how very malleable both metals are before mixture.

The sensible qualities of the different mixtures of these two metals are the following: Copper, alloyed with from one to five *per cent.* of tin, is much harder than before; its colour is yellow, with a cast of red, and its fracture is granular: it is still considerably malleable. This appears to be the usual composition of many of the ancient edged tools and weapons before the use of iron; whence it appears that the ancients did not possess (as has often been supposed) any peculiar art of hardening pure copper, otherwise than by mixture. An alloy in which the tin is from $\frac{1}{10}$ to $\frac{1}{8}$ of the whole is hard, brittle; but still a little malleable, close-grained, and yellowish-white. When the tin is as much as $\frac{1}{2}$ of the mass, it is entirely brittle, and continues so in every higher proportion. The yellowness of the alloy is not entirely lost till the tin amounts to $\frac{2}{3}$ of the whole.

Copper (or sometimes copper with a little zinc) alloyed with as much tin as will make from about $\frac{1}{10}$ to $\frac{1}{4}$ of the whole, forms an alloy which is principally employed for bells, brass cannon (so called), bronze statues, and various other purposes. Hence it is called *bronze* or *bell-metal*, and is excellently fitted for the uses to which it is applied by its hardness, density, sonorousness, and fusibility. For cannon a lower proportion of tin is commonly used. According to Dr. Watson, the metal employed at Woolwich consists of 100 parts of copper, and from 8 to 12 of tin; hence it retains some little malleability, and therefore is tougher than it would be with a larger portion of tin. A common alloy for bell-metal is 80 of copper and 20 of tin; some artists add to these ingredients zinc, antimony, and silver, in

small proportions, all of which certainly improve the sonorousness of the compound.

When in an alloy of copper and tin, the latter metal amounts to about $\frac{1}{3}$ of the mass, the result is a beautifully white alloy, with a lustre almost equal to that of mercury, extremely hard, very close-grained, and perfectly brittle. It takes an exquisite polish, which well adapts it for the reflection of light for all optical purposes. It is called *speculum metal*, and, besides the above ingredients, generally contains a little arsenic, zinc, or silver. The application of an alloy, similar to the above, to the construction of mirrors, is of great antiquity, being mentioned by Pliny. From the actual analysis, by Klaproth, of a portion of an ancient speculum, it appeared to consist of

Copper	62
Tin	32
Lead	8

Of these ingredients the last is considered by Klaproth, with high probability, as only a casual adulteration of the tin.

When the amount of the tin exceeds that of the copper, the alloy begins to lose its splendid whiteness, and acquires a bluish-grey hue; its texture likewise becomes rough-grained, and, as it were, rotten and incapable of receiving a polish.

A perfect speculum metal should be quite white, without shewing any cast of yellow when polished, not very liable to tarnish, quite free from pores, even when examined by a lens, of a certain coherence or toughness to bear the grinder, and, for the convenience of working, as soft as may be consistent with the other requisites.

Mr. Mudge, whose specula were celebrated for their goodness, observes, that the extreme of whiteness is given by 32 parts of copper and 16 of tin, but this compound is too hard and brittle; 32 parts of copper with $14\frac{1}{2}$ of tin form an alloy quite white, and as hard as can be wrought. In order that the metal should turn out free from pores, it ought to be twice fused, once for mixture of the ingredients, and afterwards, with as little heat as possible, for casting.

The following observations on the same subject are extracted from an elaborate paper by Mr. Edwards, published in the Nautical Almanack for 1787.

The quality of the copper should first be tried by adding successively from so much short of half of its weight of tin, that the mixture proves a little yellow, to the full half of tin, and by comparison of the various samples ascertaining the *maximum* of whiteness. When this is found, take 32 parts of copper, melt it, then add one part of brass and the same of silver, with a little black flux to cover the surface; when these are melted stir them together with a wooden rod, and pour in from 15 to 16 parts of tin (as ascertained by previous experiment) fused in a separate crucible, at a low heat; then stir the mixture again, and immediately pour it into cold water. Re-melt, with as little heat as possible, the alloy thus formed, and for every 16 parts take one of white arsenic, wrap it in paper, thrust the packet to the bottom of the fluid metal with a wooden rod, and stir it well as long as any arsenical vapours arise; when these cease pour the metal into a mould of sand, and as soon as it has solidified lay it in a pot full of very hot embers, and cool it very slowly: unless this precaution is particularly observed, the metal will fly in pieces when cold, or will split in the polishing.

The brass, the silver, and the arsenic in this composition appear to have their distinct use; the brass makes the mixture tougher, and somewhat softish, the silver improves its colour, and the arsenic renders the texture remarkably finer, closer, and less porous; a larger proportion of this however would make the metal liable to tarnish.

Sir J. Newton's specula were composed of 6 parts of copper, 2 tin, and 1 arsenic; they are upon the whole very good; but after being polished exhibit a rather yellow cast.

The other alloys of copper are not of much importance, and will be found under the respective metals to which they belong.

COPPER, *white*, a kind of metal white as silver, frequently brought from China, and supposed by many to be natural. But it is only an alloy of copper, zinc, and arsenic, in certain proportions. It is made with difficulty, because of the volatility of the two semi-metals; and, as its quality is noxious, it is not much used.

COPPER, in *Military Affairs*. No other metal is allowed in magazines, or for barrels of gun-powder.

COPPER, in *Calico-Printing*, a vessel in which the operations of dyeing, dunging, rinsing, &c. are performed, and which derives its name from the material it is generally constructed of. As these vessels are used indifferently for any of the above purposes, their size, form, and arrangement, are generally the same, and vary little throughout the whole kingdom. They are always circular, from $4\frac{1}{2}$ to 5 feet diameter at the top; $3\frac{1}{2}$ to four feet deep, and about the same in width, across the bottom, which is the thickest and stoutest part of the vessel. This circular form, though in general use, is perhaps the worst that could have been devised for the purpose of calico-printing. It is no doubt the first that was employed, and has advantages in point of solidity of form, and ease of transportation from one place to another, over any other. For the purpose of dyeing, however, or any operations where goods are kept for a long time at a boiling heat, and turned over the winch, it is the most inconvenient that could have been adopted.

In a vessel of this size and form, it is customary to dye from six to twelve pieces of twenty-eight yards each, at one operation. The goods are disposed either in two lengths of four or six over the winch; or, when quick turning is necessary, in one length only, in which case, six pieces, or at most eight, are disposed equally over the whole surface of the winch. In this latter case, the inconvenience of the circular form is particularly felt. It is evident that when six or more pieces are crowded upon a winch, those which are at the extremities will have little or no space in which to float, without disturbing those which are nearer the centre; whilst, on the other hand, those which are in the middle will have more than sufficient, and will float in the copper, scarcely ever touching its sides. In consequence of this, the pieces at the extremities of the winch, being crowded, will press along the sides of the copper, and thus be exposed to greater heat and hazard of copper-marking, than those which are in the middle. Their disposition on the winch will also be deranged, and the copper-man, with all his care and attention, will be unable to preserve that order and regularity in the distribution of their folds, so essentially requisite in good dyeing. When the copper is in a state of ebullition, these evils increase, and it rarely happens that the most experienced dyer can keep his goods disengaged, or prevent their getting completely fastened, when he has two lengths of six over the winch, and keeps them twenty or thirty minutes at an actual boil.

By adopting a square, or, what is still better, an oblong vessel of the same capacity as the former, these inconveniences are in a great measure done away; the goods have all equal space to float in, are equally removed from the centre and sides of the vessel, and preserve their order and disposition on the winch, even in a state of ebullition, with ease, certainty, and comparatively trifling attention.

Dye-coppers are generally set up in brick work, with each their separate and distinct fire-place, chimney, &c.

The same principles apply to the heating of these vessels as to all other boilers, but we need not enter here upon a subject which will be more fully treated of in another part of this work. The recent improvements in the application of steam, as a vehicle of heat, are however of such importance, and have at this moment excited such general interest amongst dyers, and calico-printers, as to claim a short notice in this place.

Mr Gott, of Leeds, was the first who applied steam in the large way, to the heating of dye-coppers, and the success of his experiment was so complete, as to induce many others to follow his example. This mode, which is the simplest and most economical that can be employed, consists in throwing the steam directly into the dyeing vessel. One steam boiler, situated at the extremity of the building, supplies his numerous coppers which are disposed promiscuously about the dye-house, unincumbered with fire-places, ash-pits, chimneys, &c. and simply surrounded with a casing of brick, to support the copper, and confine the heat.

The steam is conveyed in horizontal pipes, carried along the ceiling of the dye-house, from which descend vertical tubes of from $\frac{3}{4}$ of an inch to $2\frac{1}{2}$ inches diameter, according to the size of the copper they belong to. These steam tubes all pass down on the outside of their coppers, and enter them horizontally at the level of their bottoms; and are furnished with brass cocks for regulating the admission of the steam, or entirely interrupting it when the copper is not wanted.

The rapidity with which these coppers are heated, is truly astonishing. One of the largest in Mr. Gott's dye-house of 1800 gallons capacity, according to count Rumford, was brought to the boiling point in half an hour. The saving of fuel, though in general over-rated, is another advantage gained by this mode of applying heat. Mr. Gott states this at two-thirds of the quantity consumed when the coppers are heated by separate fire-places; but this is evidently too much. The saving consists in the application of fire to one vessel only of large dimensions, instead of to a number of small ones; and though this is certainly accomplished with less expence of fuel, yet, if the fire has been well and properly applied in the latter case, the saving will amount nearer to one-third than to two.

The burning of the copper sides and bottoms, when heated by a naked fire, is a heavy expence in a large establishment, and often a source of serious inconvenience. By the application of steam, this is entirely done away, and even copper vessels themselves, for many operations, rendered wholly unnecessary. Wooden vessels have been substituted, with great advantage, in their stead, and when the use of copper cannot be dispensed with, it may be employed in thin sheets, supported by a frame work of brick or wood. Important as these advantages are in an economical point of view, the system of steam-heating has, if possible, still more powerful recommendations. The ease, elegance, and regularity, with which the heat can be transmitted by a steam tube, are of themselves sufficient to entitle it to decided preference.

By the adjustment of the steam-cock, the rate of heating is so regulated, that the copper may be brought to the boiling point in any given time, with an exactness as well as celerity, unattainable by the other mode. The heat may in an instant be withdrawn, or rendered stationary at any fixed point, by a single turn of the cock, the first of which is impracticable, and the latter extremely difficult, when the coppers are heated by separate fire-places. The sides and bottom of a dyeing copper, exposed to a strong and naked fire, are always much hotter than the dye-liquor, and occasion copper-marks and unevenness in the goods, in some cases difficult to avoid. This inconvenience is entirely removed by the use of steam, since the dyeing-vessel deriving all its heat from the heated liquor within it, can never, it is evident, acquire a higher temperature.

The success of Mr. Gott's experiments was such, that many of his neighbours, at first much prejudiced against it, immediately adopted the plan. With a liberality worthy of imitation, his dye-house was open to all inquirers; and such was the interest excited by this new and extraordinary mode of applying heat, that experiments were immediately instituted in different parts of the country, with a view of extending this improvement to other branches of the art of dyeing. Mr. Gott had proved and established the practice as far as the dyeing of woollen goods was concerned, and little more remained to be done; in its application to calico-printing and the dyeing of lighter goods, however, difficulties occurred, of such a nature, as wholly to discourage many whose trials were made in a hasty ill-concerted manner, and considerably to embarrass those whose experiments were conducted with greater skill and patience.

The great, and only well-founded, objection arose from the agitation into which the water was thrown when it approached the boiling point, by which the goods were entangled and fastened, much more than in the ordinary mode. This inconvenience was not felt in Mr. Gott's dye-house, where the goods being woollen, and of much greater weight and substance, were less liable to be tossed about by the ascending currents from the steam-tubes than the thin and lighter goods manufactured from cotton. The evil was often increased by want of sufficient attention to the regulation of the steam-cock; thrice the quantity of steam necessary to maintain the copper at the boiling point being admitted, which, retaining its elastic form at that temperature, passed through the copper uncondensed, and threw the goods into the greatest confusion.

To diminish the agitation, it has been found necessary to break the force of the current, by introducing the steam in small quantities, through two or three different openings, or in some cases by introducing a false bottom, pierced full of holes, between the goods and the end of the steam-tube; by this means, and still more by carefully admitting only the necessary quantity of steam, the agitation may be so far reduced, as to be no longer troublesome.

The accumulation of condensed water in the dye-copper, is a necessary consequence of this mode of applying steam, and cannot be avoided. Where it is an object to diminish this as much as possible, it may be accomplished by using strong, or which is the same thing, very hot steam; but it does not appear that any great inconvenience results from this trifling increase, which ceases when the copper has attained the boiling point, due allowance being made for it in the first instance, when the vessel is filled with cold water.

When strong steam is rapidly thrown into a vessel filled

with cold water, the condensation is instantaneous, and attended with a loud noise, and violent shock.

We have seen a stone cistern of large dimensions, and firm joinings, nearly shaken to pieces by the incautious admission of steam, and many of the early experimenters complained that their coppers were nearly knocked to pieces, and that few would hold water after being heated once or twice.

This inconvenience may be corrected by stopping the end of the steam tube, and piercing the sides full of small holes, or, which is still better, by turning up the end of the pipe, and fixing a valve in it. In either case the steam is emitted through the openings in streamlets, or sheets of small volume, whose condensation is attended with trifling noise, and little agitation of the vessel. Several dye-houses in Lancashire and Cheshire have been fitted up on these principles, and, the coppers, thus heated, are used, with few exceptions, for every purpose of calico-printing.

Mr. Gott, as we have before stated, was the first who introduced this improvement on a large scale, the idea of which, count Rumford informs us, was derived from the perusal of his seventh Essay. We know not what share the count's publication might have in deciding the trial, but the idea of heating water by steam had occurred long before that time to Mr. Watt; and, if we mistake not, a warm bath at Soho had been heated in this way, and seen by Mr. Gott, and many others, to whom the idea of its application to more useful purposes had naturally occurred.

For some few purposes we believe this mode of applying heat, by throwing steam directly into the dye-copper, is less advantageous. When goods, for example, are kept a long time at a low heat and never boiled, the accumulation of condensed water, in this case, continues to the end of the operation, and weakens considerably the effect of the dye. All the advantages of this mode may, however, be obtained without any of the inconveniences we have before alluded to, by surrounding the dyeing-vessel with a casing of cast iron, and throwing the steam in between this and the copper. The heat in this case is transmitted through the sides of the copper, as in the ordinary mode of heating by a naked fire,

and the condensed water is carried off from the casing either by a reversed syphon, eight or nine feet long, or, when the situation will not admit of this, by a floating valve. In this way the noise and shock, from the rapid condensation of steam in cold water, the agitation in the dye-copper, and the condensed water, are all completely got rid of. The apparatus is, however, less simple and much more expensive than the former.

A strong steam is necessary to produce the boiling heat in a dye-copper cooled by the continued exposure of the goods on the winch, and the vessel and joints must be sound and strong to support this pressure. Both modes have their advantages, and will, we have little doubt, in a few years entirely supersede the ordinary mode of heating by separate fire-places.

COPPER-mark, is a stain, discolouration, and unevenness in dyed goods, caused by contact with the sides of a *hot* or *dirty* copper, during the operation of dyeing. In the ordinary mode of heating, as has been observed in the foregoing article, the bottom and sides of a dyeing-vessel, when exposed to a strong and naked fire, are much hotter than the dye-liquor. When this is the case, and the colours pale and delicate, simple contact with the hot copper is sufficient to cause unevenness, either by affecting the hue by the excess of heat, or enabling the mordant to combine with an extra portion of colouring matter. This inconvenience is in general remedied by placing a basket of wicker work within the copper, which prevents the goods from touching the sides of the vessel; it is still more completely guarded against by heating the copper with steam, in the manner already described.

The sides of a copper will often occasion marks or stains when the vessel has been negligently washed out, and especially when it has not been used for some time. A dye-copper not in use should always remain filled with clean water. It prevents the formation of a rust on its surface, which simple washing will not remove, and which acts as a mordant, and fixes the dye whenever it touches the cloth.

Copying of Letters

COPYING of LETTERS, and other writings. The celebrated Dr. Franklin made several essays, many years ago, for speedily multiplying the copies of his own hand-writing, which he exhibited to M. Alexis Rochon, of the French National Institute, and director of the Marine Observatory at the port of Brest; an account of which he has given in his memoir on the Typographic Art. This method consisted in writing upon smooth paper, with ink containing much gum, which was afterwards sanded with emery, or powder of cast-iron, and by means of a rolling-press, such as is used by the copper-plate printers, the strokes of the writing were transferred to a plate of rose copper or pewter. This plate supplies as many copies as the depth of the engraving can allow; but the copies are far from being beautiful, and the ground is spotted and spoiled. Before Dr. Franklin's process was communicated to M. Rochon, he shewed him that by writing with a steel point on a copper-plate previously varnished, a more satisfactory result might be obtained, by etching the strokes with nitric acid to a sufficient depth, for the subsequent use of a liquid ink similar to that of the printers. In this case, the plate may be wiped without precaution, and twelve or more copies may be pulled off upon coarse paper. These proofs are foul and reversed; and, therefore, in order to have them neat and in the proper direction of the writing, it becomes necessary to place the same number of leaves of white paper, wetted and prepared, upon the twelve proofs; and while the ink is still fresh, the whole being passed together through the rolling-press, the same number of leaves of counter-proofs are obtained as there were proofs; so that instead of twelve turns of the press, thirteen will be required to supply twelve counter-proofs, very black, neat, and legible, even when the plate has not been perfectly wiped. This method is certainly not to be compared with fine engraving; but it may be useful in military operations, and all other cases in which a speedy multiplication of copies is required. No precaution is here necessary; whether the nitrous acid be more or less strong, or remain a longer or shorter time upon the plate, or whether the plate be somewhat heated to increase the strength of the solvent, the process of the operation will never fail; provided the steel point made use of to trace the characters through the varnish, shall lay the copper perfectly bare. It is of advantage that the nitric acid should bite deep, because the counter-proofs are, by these means, much darker. The plate need not be well wiped, because it is of no consequence whether the proof which is used to afford a counter-proof should be very clean, provided that it does not spot the copy intended to be procured. The most liquid kind of printers ink may be used. See ENGRAVING and STEREOTYPE.

In 1780, Mr. James Watt, of Birmingham, obtained a patent for a new method which he had invented to this purpose; of which the following description is given in his specification: Let the letter or other writing, that is intended to be copied, be written with the ink hereinafter described, or with any other writing-ink fit for the purpose. Take a piece, or pieces, of thin paper which contains no size, or glue, or gummy or mucilaginous matter, or which at least does not contain so much size, or other matter, as would make it fit for being written upon. Cut this paper, or papers, to the size and shape of the writing of which a copy is wanting; moisten or wet the same thin paper with water, or other liquid, by means of a sponge or brush, or by dipping, or otherwise. Having moistened or wet the thin paper, lay it between two thick unsized spongy papers, or

between two cloths, or other substances capable of absorbing the superfluous moisture from the thin paper; when it has been slightly pressed between such thick spongy papers, or other substances, by the hand or otherwise, lay the said thin paper, so moistened and pressed, upon or under the side of the writing which is to be copied, and in such manner that the one side of the said moistened paper shall be in contact all over the side of the said writing, so intended to be copied; and that to the other side of the said moistened thin paper, there shall be applied a piece of clean writing-paper, or cloth, or other smooth uniform substance. Lay the said writing intended to be copied, with the thin moistened paper intended to receive the copy, (placed respectively as above directed,) upon the board of a common rolling-press, or of that of which a description and drawing are hereunder written and drawn, and press them once, or oftener, through the rolls of the said press, in the same manner as is used in printing by copper-plates; or, instead of using the said or any rolling-press, squeeze the said papers, placed respectively in the manner above described, in a screw-press; or subject them to any other pressure sufficient for the purpose; by means of which pressure, in whatever manner applied, part of the ink of the writing intended to be copied shall press from the said writing into, upon, and through, the said thin moistened paper, so that a copy of the writing, more or less faint, according to the quality of the ink and paper employed, shall appear impressed on both sides of the said moistened paper, *viz.* upon one of the sides in the natural or proper order and direction of the lines, as they are in the original writing, and on the other side in the reverse order and direction. But, in order to make the impression or copy of the writing more strong, legible, and durable, it is proper and useful to moisten the said thin paper, which is to receive the copy or impression, with the following liquor, instead of water or other liquid, and to proceed in all other respects as is above directed; or to moisten the said thin paper with the following liquor, and to dry the said paper, and, when a copy of a writing is required to be taken, the said paper, thus previously prepared and dried, ought to be moistened with water or other liquid, and to be proceeded with in all other respects as has been directed. The said liquor to be used for moistening the said thin paper, or for preparing the said paper previously to its being used, is made in the following manner: Take of distilled vinegar two pounds weight, dissolve in it one ounce of the sedative salt of borax; then take four ounces of oyster-shells, calcined to whiteness and carefully freed from their brown crust, put them into the vinegar, shake the mixture frequently for four-and-twenty hours, then let it stand until it deposits its sediment; filter the clear part through unsized paper into a glass vessel, then add to the said mixture or solution two ounces of the best blue Aleppo galls bruised, and place the liquor in a warm place, shaking it frequently for twenty-four hours; then filter the liquor again through unsized paper, and add to it, after filtration, one quart, ale measure, of distilled or other pure water. It must then stand twenty-four hours, and be filtered again if it shews a disposition to deposit any sediment, which it generally does. The liquor, thus compounded and prepared, is to be used as hath been directed.

N. B. In place of the vinegar, any other liquor impregnated with a vegetable acid may be used; and, in place of the galls, oak bark, or any other vegetable astringent, or substance which is capable of becoming black, or deep coloured, with solutions of iron; and, in place of the oyster-

shells, any other pure calcareous earth may be used. But if the impressions are not wanted to be very black, and the writing ink is good, water itself may be used to moisten the thin paper, as herein first directed. It may be found necessary to add more or less water, in the preparation of the above liquor to be used for moistening the thin paper, or to vary the proportions of the other ingredients, according as they are more or less perfect or strong, or as the impression is required to be more or less deep coloured. The writing-ink, which the patentee uses for letters or writings intended to be copied, is prepared as follows: Take four quarts, ale measure, of spring water; one pound and a half, avoirdupois weight, of Aleppo galls; half a pound of green copperas or green vitriol; half a pound of gum-arabic; four ounces of roach-alum; pound the solid ingredients, and infuse them in the water six weeks or two months, during which time the liquor should be frequently shaken; strain the liquor through a linen cloth, and keep it in bottles, closely corked, for use.

Plate III. Miscellany, fig. 1. represents a front or end view of the rolling-press invented by Mr. Watt, and referred to in the above specification. ABC is one of the ends of an iron or wooden frame, which serves to connect the two rollers. D, D, are two wooden or metalline rollers, turned extremely exact, or truly cylindrical, and which are mounted on iron axles, firmly fixed in them. EE is a double-ended lever, by means of which the roller, on whose axle it is applied, may be forcibly turned round. FF represents the board of the rolling-press, on which the writings to be copied are to be laid. NN is a piece of cloth, or other elastic pliable substance, placed next the roller, and above the writings to be copied; and the board, G, is a strong plank of wood, or plate of metal, serving to connect the two end-pieces of the frame at bottom. HH represents the edge of a common table, to which the press may be fastened by the iron screw-cramps I, I. K is a slit, of which there is one in each end-piece of the frame; these slits are filled with elastic steel, or other metalline springs, or with some other elastic substances which serve to press the two rollers forcibly together. L is a brass bolster, supported upon the springs, and serving to support the end of the axis of the under roller.

Fig. 2. represents a side view of the rolling-press, in which A B, A B, are the two end-pieces of the frame. D, D, are the two rollers. E is the double-ended lever. G is a strong plank, or plate of metal, which forms the bottom of the frame. HH is the table on which the press stands. I is one of the iron cramps which fasten the press to the table; and M is a bar of iron which connects the upper part of the frame.

Fig. 3. represents a screw-press, which may be used, instead of the rolling-press, in taking off impressions from writings. AA is a double-ended lever. BB the screw. C a block of wood, or metal, which the screw acts upon, and which is attached to it. DD the frame of the press, made of iron or wood. EE is a moveable board, on which the writing to be copied is to be laid, with a cloth over it. FF the bottom or sole of the press, made of wood or metal. Be it remembered, that these presses are made of different sizes, according to the sizes or largenesses of the writings intended to be copied. These now referred to are drawn from one sufficiently large to take an impression from a folio page of writing or post paper, and are drawn to a scale of one inch and a half for each foot, or one-eighth of their natural size.

Fig. 4. represents one of Hawkins's patent polygraphs, for making two or more copies of any writing at once. AAB, is an upright frame, from the upper piece of which is suspended a double parallel ruler, DD, EE:

dd, ee, is another similar parallel ruler, of which *fig. 5.* is a plan, fastened to the board, FF, of the instrument. These two rulers are connected to a stout bar, G; the vertical one, DD EE, by pivots at the end of the bar, H, *fig. 4.* going into holes in the projecting part of two pieces of brass, gg, at each end of G; and the horizontal one, dd ee, by pivots at the ends of its corresponding bar, b, working in holes in another arm of the same brasses. The pens are connected with the bar, G, by a curved brass limb, a, turning on a screw put through the bar, G, as a centre. On the other side of the bar is a short arm, b, in the same piece with the limb: this is jointed at its upper end to the end of a small rod, i, the other end of which is jointed to another exactly similar limb, carrying the other pen. The pens are fitted into a small tube, called the pen-tube, having a shoulder at its upper end. This fits tight into another tube, in the same piece with the curved limb, and is pushed in as far as the shoulder of the pen-tube will allow.

The weight of the machinery is suspended by eight small spiral springs, I, fastened to a ring fixed to the bar, G; their upper ends are connected with the end of a double jointed lever, K, which can follow the motion of the bar, G, without stretching the springs too much. The rod, L, by which the perpendicular motion is suspended, turns upon pivots working in pieces of brass beneath the piece, B: the right hand one is called a regulator, and has two screws, one moving the pivot vertically, and the other horizontally, for adjusting the instrument. The two bars, ee, of the horizontal motion are connected with dd by pivots at the end of b, so that dd can be lifted up without moving the other, whose weight is supported upon two small brass wheels i, i. The frame, AAB, when the instrument is not in use, turns down on the board, FF, and is kept fast by a spring lock, which is opened by pushing in a round button, k. The frame now forms the sides, and the front board becomes the lid, and, when shut down, is locked by a lock, M. In explaining the use of the instrument, we cannot do better than copy the printed directions fold with the instrument. Choose two goose quills, taking care they are of the size wanted; make them into pens, and put them into the pen-tubes. Having introduced them with the nibs first, apply the shoulder end of the pen-tube against the semi-circular hollow, in the upright part of the gauge, Q, *fig. 4.* and push the pen through the tube, till the nib reaches a line drawn across the end of the gauge; slide the pen-tube into the fixed socket, until the shoulder of the pen-tube stop it, holding by the fixed socket, and not by the work, so as not to strain the machinery. If the polygraph is in order, the pens will now write, draw, or copy whatever may be required, with the greatest exactness. To prove the machine's being in order, bring the pens to the upper part of the paper, and try if they both touch; if not, with a small screw-driver turn the perpendicular screw of the regulator, till they touch equally. Bring the pens to the bottom of the paper, and move the horizontal screw till they both touch. When a pen wants mending, nothing more is necessary than to take the pen-tube out of the socket, mend the pen, gauge it, and return it into the socket again. When the machine is out of use, wipe the pens clean, and place the left one, with the curved limb, on the hook beneath the horizontal rulers. Let down the frame, AAB, which fastens by a spring-lock, and at the same time raises the writing-board, which then becomes the lid of the portable case for the polygraph.

The patent now belongs to Mr. Farthing, Cornhill, who manufactures the instruments.

These instruments are made with three, four, and five pens, and answer the purpose very well.

Cordage

CORDAGE, is used, in *general*, for all sorts of ropes and cords, great and small; and more particularly for those that are used in the rigging and fitting out of small vessels. The word is also used for the art of preparing and manufacturing the ropes, &c. See CABLE. See also ROPE, and RIGGING.

The naval cordage of different ages and nations has been formed of very different materials. Those of the earlier ages were probably thongs of hide or leather; the use of which was retained by the Caledonians in the third century, and by the nations north of the Baltic in the ninth and tenth centuries. They are even now used as ropes in the western isles of Scotland. These were superseded in the southern parts of Britain, and on the continent, at an early period, by iron chains. Accordingly we find, that in the maritime and commercial country of the Veneti, who were intimately connected with the Belgæ of Britain, iron chains were used for cables in the days of Cæsar. However, in the more improved countries of the south, thongs of leather and chains of iron had long given place to the use of vegetable threads; and the art of combining them into strong cords was understood and practised. In this manner the Greeks used the common rushes of their country, and the Carthaginians applied to the same purpose the spartium or broom of Spain. And as all the cordage of the Romans was formed of these materials, at their last descent on our island, the art of manufacturing them would necessarily be introduced with the Roman settlements among the Britons. Under the direction of the Roman artists, their *junci*, or rushes, would be wrought into cordage. Accordingly the remains of old cables and ropes are still distinguished among the British sailors, by the name of "old junk." Moreover, the Roman sails, which, in the days of Agricola, were composed of flax, were afterwards made of hemp; and our own are therefore denominated *cannabis*, or "canvas," by our present mariners. About the same period, the same materials were substituted for the junk of the British cordage; for the use of hempen ropes upon land, and of hempen nets for hunting, was very common among the Romans in the first century. The Indians still make their cordage of the bark of cocoas, and

other trees, and of fibres of plants. The cordage of the British navy is made of the Riga or best Petersburg break hemp, and tarred with good Stockholm or Russia tar.

The cordage is said to be *baked*, when, having passed a stove, or other hot place, it is drained of all its moisture. *White* cordage is that not yet pitched. *Cordage pitched in the stove*, is that which is passed through hot pitch as it comes out of the stove. Each quintal of cordage may take up about twenty pounds of pitch. The cordage is sometimes pitched in the thread. For the method of making ropes and different sorts of cordage, see ROPE-making.

By 25 Geo. III. c. 56. no person shall use, in the manufacture of any ropes for shipping, (or sell the same,) hemp called sheet chucking, half clean, whale line, or other topping, cordilla, damaged hemp, or any hemp from which the staple part thereof shall have been taken away by the manufacturer, on pain of forfeiting, for the manufacturer, such rope, and treble the value of it; and for the vender, not being the manufacturer, a sum equal to treble its value. For the better distinguishing the quality of such ropes, that which is inferior to clean Petersburg hemp shall be deemed *inferior* cordage, and marked accordingly, by running from one end of it to the other three-tarred mark yarns, spun with turn contrary to that of rope yarn, and also one like tarred yarn in every other rope for the use of shipping; and the maker shall mark or write, on a tally to be affixed on it, the word "staple," or "inferior," (as the case shall be,) and also his name, signed by himself or his attorney, together with the name of the place where manufactured; and in default thereof, shall forfeit 10s. for every hundred-weight. And if any such rope-maker shall wilfully or knowingly permit his name to be put to any such ropes, not being of his own manufacture; or if the vender or proprietor, or any other person, mark upon the tally the name of any person, not being the manufacturer, he shall forfeit 20l. And if any person shall make any cables of any old or worn stuff, which shall contain above 7 inches in compass, he shall forfeit four times its value. Foreign-made cordage, for which no duties have been paid, belonging to a ship owned by any of his majesty's subjects, resident in Great Britain, or the British

colonies, and entering any port in this kingdom, shall be duly entered on oath at the custom-house (standing and running rigging excepted); and before the ship be cleared inwards, the master shall pay the duties, on pain of forfeiting the cordage, and 20s. for every *cwt.* of it. Upon the importation of cordage, tarred or untarred, there is a duty payable of 8s. 6d. *per cwt.*, and no drawback allowed upon exportation; and in the port of London there is a farther scavage-rate of 1d. *per cwt.* of 112 lbs. upon the importation of cable-ropes for cordage.

As to the strength of ropes, or cordage, M. Reaumur takes occasion, in the Memoirs of the Royal Academy, to consider the question, whether a rope composed of several twists, or strands, interwoven, *v. gr.* ten, have more strength to sustain a weight, than the ten twists would have separately, placed parallel over one another; or, which is the same thing, whether, if each twist be capable of sustaining the weight of a pound, the whole cord be able to sustain more than ten?

On the one hand, 1. By virtue of the twisting, the diameter of the rope is made larger than are those of the ten twists together; but it is apparently by its thickness that a rope sustains a weight, or resists a fracture. 2. Twisted strands have not all, as when parallel, a vertical direction with regard to the weight: several of them, and even the greatest part, have oblique directions, and of consequence do not bear all the share of the burden they would otherwise bear. In effect, they are inclined planes that are only pressed with a part of the load.

Hence it would follow, that the surplus of the strength of the twists might be employed in raising a larger weight.

On the other hand, it is true, that, in twisting the strands, some are stretched, and others left more loose; and the new tension given the former, serves to weaken them, and has of itself the effect of a weight: thus they become less able to sustain one so large. Those more lax, on the contrary, evade, in some measure, the action of weight: for the action is distributed equally on the ten supposed equal twists; and if some, by reason of their particular disposition, receive less than their quota, the weight will act more forcibly on the rest, and will break them first, as being more tense; after which, it will easily dispatch the rest, as not being in sufficient number to oppose it.

This is the sum of what can be urged for and against the twisting: to decide between them, M. Reaumur had recourse to experiment. The result was, that, contrary to all expectation, he still found the twisting diminished the strength of the rope: whence it is easily inferred, that it diminishes it the more, as the rope is the thicker. For inas-

much as the twisting diminishes; the more twisting, the more diminution.

The resistance or friction of cordage is very considerable; and by all means to be considered in calculating the power of machines. M. Amontons observes, in the Memoirs of the Royal Academy, that a rope is so much the more difficult to bend, 1. As it is stiffer, and more stretched by the weight it draws. 2. As it is thicker; and, 3. As it is to be more bent; *i. e.* as it is to be coiled, for instance, into a smaller ring.

The same author has thought of ways to prove, in what proportion these different resistances increase: that arising from the stiffness or rigidity occasioned by the weight which draws the rope, increases in proportion to the weight; and that arising from its thickness, in proportion to the diameter. Lastly, That arising from the smallness of the gyres, or pulleys, about which it is to be wound, is indeed greater for smaller circumferences than large ones, but does not increase so much as in the proportion of those circumferences.

On this footing, the loss a machine sustains by the cordage, being estimated in pounds, becomes, as it were, a new weight, to be added to that which the machine is to raise. This augmentation of weight will render the cords still the more stiff; which excess is to be computed as before.

Thus we shall have several sums still decreasing; which are to be added together, as in the article of friction; and it will be surprising to see what a sum they will amount to. See FRICTION.

Where ropes are used in a machine, all the resistance resulting from their stiffness is to be put together; and all that occasioned by the friction; which will make so considerable an augmentation to the difficulty of the motion, that a power which to raise a weight of 3000 pounds, by means of a fixed and moveable pulley, needed only 1500 pounds, must, according to M. Amontons, have 3942 pounds, on account of the frictions, and the resistance of the cordage.

CORDAGE, *twice-laid*, is that which is made of cast rigging, as shrouds, stays, mooring and other cables, which, if not much worn, will make good ropes for wetting the sides of ships, worming and wooding for cables, spun-yarn for seizing, worming for large stays, seizing for stops of blocks, small cable-laid ropes for warping ships, rat-lines, scaffolding-ropes for dock-yards, &c. When the yarn of this old stuff is overhauled, a little thin tar should be poured on it, which will make it pliable and lie better. The yarn unfit for knotting will pick into oakum for caulking.

Cork

CORK, the exterior bark of a tree belonging to the genus of oak (*Quercus Suber*), which grows wild in the southern parts of Europe, particularly France, Spain, Portugal, and Tuscany. When the tree is about 15 years old, it is fit to be barked, and this can be done successively for eight years. The bark always grows up again; and its quality improves as the age of the tree increases. If care is not taken to strip the bark, it splits and peels off by itself, being pushed up by a second growth forming under that of the preceding year.

Stripping and preparing the Bark.—The bark is taken off by the Portuguese in sheets or tables, by cutting it with knives having two handles, similar to those which the tanners or skinners use at their beam, or horse, sitting it down after the circular incision is made, from top to bottom; to effect this incision they ascend the tree by a ladder to the part where the branches spring from the top; they then make a slice or slip: the filaments connecting the bark with the trunk are next cut down, or through, by a knife formed like our hay-spade, and which they use in nearly the same manner: the bark is frequently, through haste, broken off

at the root, in which case the two ends are distinguished by the appellations of "cut end" and "fast end;" the first is that which had been at the top of the tree, where the circular cut was first made, and the second is that which had been next the ground.

Another mode of accomplishing the artificial stripping of the tree, is thus performed: several incisions are made from the top of the trunk to the bottom, and at each extremity of these incisions a circular cut is effected; by this operation the bark is cut off from communication with either the lower or higher parts of the tree; consequently it is entirely deprived of support; in a little time it loosens, and its separation is completely accomplished by the hand; thus the progress of nature is expedited by very simple means. Before the operation of barking is again performed upon the same tree, should it be a young one, it ought to stand three years; it is not however unfrequently cut within the period; when it is cut too young, it is generally preserved by the English cork-cutter in his cellar till it alters from green to the colour proper for his purpose, which is effected merely from the time he keeps it in that state, though after all, it is still much inferior to that taken when the tree has arrived at maturity.

After being detached from the tree, the Portuguese "burn it," laying the convex side of the bark to the fire; in this operation they are careful to cover all the blemishes they possibly can, holes are filled up in an insufficient manner either by the swelling and straightening of the wood upon the fire, or by the artful introduction of soot and dirt. When the judgment of the burner is sufficiently exercised in flattening the bark, and artificially repairing its defects, it is laid into the farm yard for sale, in stacks, and bought by the merchants from thence for exportation.

Another method used in straightening the bark, is to pile it up in pits, loaded with heavy stones, by which method it becomes flat, this is afterwards more completely effected in a damp cellar, and is called "laying the cork;" when this operation is finished it is dried over a strong fire in what is called "a burning yard;" from negligence in this process it receives too much of that black colour which is so frequently discovered in articles made of cork: when sufficiently dried it is ready for stacking.

The cork is not burnt, but only charred on each surface; previous to this operation the pores of the bark are open, and its consequent sponginess of texture would make it not only give too much way to the knife; but particularly in the case of "taps" and "bungs" would render it a filter, rather than a preserver, of liquids. It shrinks with the application of moderate heat, and thereby closes the pores, by which any filtration might be effected. If "burning" ever be used as a cover for defects, it is not an original design but an accidental advantage, which is taken of a necessary process; "bungs" and "taps" are always charred on both surfaces; good bottle corks, though the bark of which they are made is likewise subjected to the operation of fire, do not after they are cut exhibit any marks of that element, being cut in the length way of the wood, the pores lie in a contrary direction, and the charring consequently is taken off by the process of rounding them.

The cork tree as well as the uses to which the bark is applied, &c.—This tree, as well as its use, was known to both the Greeks and Romans. By the former it was called *phellus*. Theophrastus reckons it among the oaks, and says, that it has a thick fleshy bark, which must be stripped off every three years to prevent it from perishing. He adds, that it was so light as never to sink in water, and on that

account might be used with great advantage for a variety of purposes. That the *suber* of the Romans was our cork-tree is generally and justly admitted. Pliny relates of it every thing said by Theophrastus of the *phellus*; and from his account we learn, that at the period when he wrote, cork was applied to as many purposes as at present. At that time fishermen made floats to their nets of cork; that is, they affixed pieces of cork to the rope which formed the upper edge of the net, in order to keep it at the surface of the water. Another use to which cork was applied, according to Pliny, was for anchor-buoys. "*Usus ejus ancoralibus maxime navium*:" that is, as this passage may be interpreted, it was used for making buoys, called "*Ancoralia*," which were fixed to the cable, and by floating on the surface of the water, over the anchor, pointed out the place where it lay. Our navigators use for that purpose a large but light block of wood, which, in order that it may float better, is often made hollow. See BUOY.

Another use of cork among the Romans was for being made into soles, which were put into their shoes, in order to secure their feet from water, especially in winter; and, as high heels were not then introduced, they served the purpose of elevating ladies and making them appear taller than they naturally seemed. The practice of employing cork for jackets to assist in swimming is also very ancient; for we are informed, that the Roman whom Camillus sent to the capitol when besieged by the Gauls, put on a light dress, and took cork with him under it, because, to avoid being taken by the enemy, it was necessary that he should swim through the Tiber. When he arrived at the river, he bound his clothes upon his head, and placing the cork under him, was so fortunate as to succeed in his attempt. The most extensive and principal use of cork at present is for stoppers to bottles. To this purpose it is excellently adapted; because it is very light, may be easily compressed, and expands again by its elasticity as soon as the pressure upon it is removed, and, therefore, it fills and stops up very closely the space into which it has been driven by force. Besides, it may be easily cut into all forms; and though it abounds with pores, which are the cause of its lightness, it suffers neither water, beer, nor any common liquid to escape through it, and it is but slowly and after a considerable interval that it can be penetrated even by spirits; its numerous pores seem to be too small to afford a passage to the finest particles of water and wine, which can with greater facility ooze through more compact wood that has larger or wider pores. This use of corks was not altogether unknown to the Romans; for Pliny expressly says, that it served to stop vessels of every kind, and instances of its being employed for that purpose may be seen in Cato (*De Re rustica*, cap. 120.) and Horace (*lib. iii. od. 8. 10.*); its application to this use does not seem, however, to have been very common as other substances have been generally employed for this purpose. Stoppers of cork seem to have been first introduced after the invention of glass bottles, of which no mention occurs before the 15th century. See BOTTLES.

This wood is still formed into soles for shoes, into corks and bungs for stopping bottles, &c. into a floatage for the nets of fishermen; it is employed generally, though perhaps with a considerable degree of error in teaching the art of swimming; it is also ingeniously used on account of its lightness, when an amputation of the human leg has been necessary, to supply the deficiency; the Spaniards line stone walls with it, which not only renders their houses very warm but corrects the moisture of the air; the Egyptians made coffins of it, which being covered in the inside with a resinous com-

position preserved their dead bodier. It is burnt to make that light black substance called Spanish black, from its having been first made in Spain.

Cork bark has not only been applied as above, but also in the preservation of life, when endangered by shipwreck; the most conspicuous exhibition of its advantages is in the application of it in the construction of the "life boat" or "cork boat," as it was originally called. We have under the article *boat*, "*life boat*," given our readers a short account of that inestimable invention; since which we have procured a very valuable account by the principal secretary of the meeting who first advertised the reward; we have also obtained from the liberality of Mr. Greathead, and the interest of the gentleman alluded to, a plan or section of the boat, drawn by the original inventor, which will be given under the article *LIFE BOAT*.

A cork jacket too has been revived from an old German discovery, by Mr. Dubourg; to preserve the lives of persons in danger of drowning, which is constructed as follows. Pieces of cork about three inches long, by two wide, and the usual thickness of the bark, are inclosed between two pieces of strong cloth or canvas and formed like a jacket without sleeves; the pieces of cloth are sewed together round each piece of cork, to keep them in their proper situations; the lower part of the jacket about the hips is made like the same part of women's stays, to give freedom to the thighs in swimming; it is made sufficiently large to fit a robust man, and is secured to the body by two or three strong tapes sewed far back on each side, and tied before; the strings are thus placed to enable any wearer to tighten it to his own convenience.

Cork in its action has the elasticity of a spring, and when pressed into any aperture, it exerts a force acting outwardly on all sides from the centre. It is this quality that makes it valuable in shutting out the external air from liquors, and elastic fluids; and it is fitted for this purpose in a degree proportioned to the impermeability of its pores. The elasticity of cork has also been employed for many other purposes in the arts; it forms the spring of the lifter in ordinary candlesticks, and where the frame is not heavy, it can be made into a good substitute for the pulleys and weights of the fashies of windows. See *CANDLESTICK* and *WINDOW-SASH*.

Other vegetable productions have likewise been occasionally employed possessing qualities similar to cork. The *Spondias lutea*, a native of South America, which flourishes in moist situations, and which is there called monbin or monbain, is sometimes brought to England, as a substitute for cork. The roots of liquorice are applied to the same use, and on this account, as well as its medicinal properties, is much cultivated in Slavonia, and exported to different countries. The tree called myssa, which is found in North America, has also been applied to similar purposes.

CORK-CUTTING, or the *Manufacturing of Corks*. This business, though it is thought one of the most dirty, is not one of the least profitable; it is likewise easy in the acquirement. The cork, after being pressed into square pieces, as above noted in the treatment of the bark, is received by the cork-cutters, and if not sufficiently flat for their purpose, they "lay" it again over a fire in their "burning yard," turning the convex part to the flame; the heat by twisting the edges of the bark, counteracts the natural bend, and compels it to receive a flat form. During this operation, a considerable degree of attention is paid to smoothing it, and particularly again to cover its defects. It is next cut into slips, narrow or wide, according to the intended cork, bung, or tap, for such are the names of the general divisions

in this business. The use of the two former is well known, the latter is used for stopping the tap-holes of barrels, as the name implies. These slips are again cut into squares, of a length proportioned to the use they are intended for. This operation is performed by one man, from whom they are handed forward to several others. A further division of corks takes place, of these different sorts according to their lengths, and are denominated "short," "short long," and "full long."

The cork-maker places himself before the table or plank, on which is fastened a board about three inches thick, four broad, and twelve long: immediately on a line with his left hand is a piece of wood, rising about four inches from the board, and fixed about the middle of it, on which the cork is laid, after being cut as above. This wood not only supports the cork, and is as a guide to the workman, but by its elevation above the board, gives room for the knife to cut a part of the cork in a smooth and circular manner, without striking on the table below. The piece is then turned to where the last cut ceased, and this is continued until the knife has gone completely round; the top and bottom are then pared level, and the cork thrown into a box or basket, with the rest of the same length. As the bark is not of the same quality throughout each piece, the corks are sorted by a boy into four kinds, "superfine," "fine," "common," and "coarse," and are sold accordingly.

The only tool employed by the cork-cutter is a knife about three inches broad in the blade, and about six inches long, very thin and sharp, and equal in breadth from the handle nearly to the end, which is finished by a gentle curve. This knife he sharpens upon the board where the guard is placed, by one whet or stroke on each side, after every cut, and now and then upon a common whet-stone.

From the foregoing review it is evident, that the art of a cork-cutter is principally to obtain a regular, round, and quick turn of the wrist, in guiding the knife so as to complete a pretty correct circle, and to make a smooth surface; it is on this account that the knife must be particularly sharp, to enable the workman to turn it with ease.

The parings of the cork are carefully kept, and sold to the dry colour makers, to be burnt into Spanish black.

It may be supposed that those who give the detail of any manufacture would be the best able to point out improvements in it, though this is not always the case; yet one improvement in the "laying" of the cork wood, appears of great importance to the writer of this. In the present mode, a great deal of time is lost in placing and removing the stones used to flatten the bark; and though the weight may be moderated or introduced by degrees, yet it cannot be done in that regular manner which appears the most likely to effect the purpose. In addition to which it may be observed, that in proportion as the weight is carelessly applied, will be the risk of breaking those pieces which most partake of the circular bend of the tree. To remedy this inconvenience, and to do away the old, gross, and cumbersome method, a screw might be used, such as that employed by the printers in pressing their work; by its operation a gradual pressure would be given, the former objections done away, and a much neater and workman-like method adopted.

Cutting the cork into stripes might also be accomplished with much greater facility; the whole breadth of the cork might be cut by one stroke, by means of semi-circular knives, like small cheese knives, set at certain distances, in a frame, which, by being affixed to a pole, with a cross-bar as a handle, might be driven through the whole breadth, in

the same time that a single slip is cut by the present method.

CORK, Acid of, in *Chemistry*, a yellowish thick acid matter obtained by distilling four times its weight of nitrous acid from cork. This is soluble in water and has an austere bitterish taste. It does not crystallize, but becomes consistent like wax by evaporation; is soluble in ardent spirit; forms deliquescent salts with the earths and alkalis; and has as strong an attraction for lime as the acid of sugar.

CORK, Mountain, *Suber montanum*, or *Corium montanum*, in *Mineralogy*, a species of the muriatic genus of earths and stones, according to the arrangement of Kirwan (*Mineral. vol. i.*) Its colour is white, or reddish-white, or yellowish-grey, or isabella, or ochre-yellow, or yellowish-brown. It is found either in thick compact pieces, and then called "mountain cork;" or in thin flat pieces, then called "mountain leather or paper;" or cellular, and then called "Caro montana, &c." The lustre is 0, rarely 1, and transparency 0. Its fracture presents fibres confusedly interwoven with each other, sometimes so subtle as to be distinguished with difficulty, and thus they give the fracture a compact earthy appearance. Hardness 4; it takes an impression, or yields like cork to the finger, and is somewhat elastic. Sp. gr. before it is penetrated by water, from 0.6806 to 0.9933; and after admission of water, from 1.2492 to 1.3492. (Brisslon.) If perfectly dry, and sufficiently thick, it gives a sound when struck. It feels meagre. Bergmann and Saussure found it fusible, though with difficulty, by the blow-pipe. By Mr. Bergmann's analysis it contains from 56 to 62 per cent. of silex, 22 to 26 of

aërated magnesia, from 2.8 to 12.7 of argill, about 3 of calx of iron, and from 10 to 12.7 of aërated calx.

CORK-screw, in *Mechanics*. *Fig. 1. Plate XVII. Mechanics*, is a simple cork-screw, consisting of a screw, A, turning in a female screw attached by two small rods to the collar B, which receives the neck of the bottle from which the cork is to be extracted; the two rods have a groove in them to receive the ends of a cross piece, connected with the cork-screw, and prevent its turning round with the screw A.

Fig. 2. is nearly the same, except that the nut, B, is turned instead of the screw.

Fig. 3. is called the *ne-plus-ultra* cork-screw; it consists of two cork-screws A, B, one within the other; the screw which enters the cork is fixed to the internal one. In using this instrument both screws are screwed up to their shoulders, and the whole is turned round together till the cork-screw has penetrated the cork. The handle and the two screws are then turned in the same direction, without permitting the frame to turn till the cork is drawn. The handle is then turned the contrary way, and the screw drawn out of the cork by means of the small screw B.

Fig. 4. is a screw of nearly the same kind, a rack and pinion being substituted for the screw B.

A corking-machine is represented in *fig. 5*; in which A is a treadle to be worked by the foot; it is connected by a rod *d*, with an iron-lever D; the bottle to be corked is placed in a leathern case E, fastened to a board sliding in a groove; the cork is inserted, and the bottle slid under the lever D, the foot is then placed on the treadle, and the cork forced in; the corks are first pinched by placing them under the lever at *d*, to make them enter easily.

Cornwall

CORNWALL, in *Geography*, the name of the most western county of England, is nearly insulated by water; having the British Channel on the south, and the Bristol Channel on the north; both seas seeming to meet near the point called the Land's End, at the extremity of the promontory on the west: on the east it is separated from Devonshire, by the river Tamar, and an artificial boundary of a few miles at the northern extremity. From this boundary the land continually contracts its breadth to the westward, assuming something of the appearance of a cornucopia. The widest part of the county, from Morvinstow on the north, to the Rame-Head on the south, is about forty-three miles, but, from its rapid contraction, twenty miles may be considered as a medium. From Mount's bay to St. Ives, it is not more than five and a half miles across. The length of the north-east side from Morvinstow to the Land's End, is about ninety miles. The circumference is estimated at two hundred. There is a tradition that a considerable tract of land, named the *Lioues*, formerly connected with this county, and extending towards the isles of Scilly, was, at a very remote period, ingulphed by the ocean.

The original British name of Cornwall appears to have been *Cernycu*, i. e. a horn or promontory; and, is supposed, by Dr. Borlase, to have been changed, by the intercourse of the natives with Romans, into the Latin term *Cornubia*, "which it retained till the Saxons imposed the name of *Weales* on the Britons, driven by them west of the rivers Severn and Dee, calling their country in the Latin tongue, *Wallia*; after which, finding the Britons had retreated, not only into Wales, but into the more western extremities of the island, the Latinists changed *Cornubia* into *Cornwallia*; a name not only expressive of the many natural promontories of the country, but also that the inhabitants were Britons of the same nation and descent as those of Wales; and from this *Cornwallia*, is derived the present name Cornwall." Borlase's *Antiquities of Corn-*

wall. This portion of the kingdom was included by the Romans under their first division, *Britannia Prima*; but antiquaries differ as to the extent of the Roman dominion in this part of the country. It is supposed that the Romans made an actual conquest of Cornwall about the same period that Claudius subdued the southern part of the island: this opinion is strengthened by many coins, pavements, urns, and sepulchres that have been discovered in different parts of the county, chiefly within the last century; and is further confirmed by the form of various forts, encampments, and road-ways. Dr. Borlase observes, that the collective mass of evidence, in favour of the Roman domination here, is so strong, that "it cannot be contradicted." Cornwall, from its soil, appearance, and climate, is apparently one of the least inviting of the English counties. A ridge of bare and rugged hills, interspersed with bleak moors, runs through the midst of it. The roads, which are chiefly carried over the higher lands, or extensive commons, convey to the traveller a much greater idea of sterility than the produce of the country will warrant; for marks of abundant fertility are displayed in the vallies, and on the sea-shores; the use of the sea-sand and weeds collected on the beach, greatly increasing the richness of the soil. The surrounding body of water renders the air extremely moist; and the interception of the clouds, by the central high lands, occasions frequent and heavy showers: these, however, are of short duration, and may be considered as conducive to health, by dissipating the noxious vapours arising from the processes of refining the ores, and introducing the vivifying qualities wafted by the genial breezes from the ocean. The seasons are more equal than in most parts of England, being generally free from intense heat or piercing cold. Frosts seldom continue long; and the snow scarcely ever continues on the ground longer than two or three days. The sea-air is considered as injurious to vegetation, the salt particles wherewith the atmosphere is impregnated, together with the violence of the

winds, prevent the growth of trees on the coasts; and it is only in the sheltered vales that the ancient natural woods are to be found. The attempt to raise plantations, in situations exposed to the south-west and northerly blasts, was hardly ever successful till within these few years, when more promising indications have attended it; the pine-after fir being first planted as a shelter to the more tender trees. The art of husbandry appears to have been but little practised in this county, so late as three centuries ago. "Their grounds," says Mr. Carew, "lay all in common, or only divided by *stiche meale*, and their bread corn very little: their labour horses were only shod before; and the people devoting themselves entirely to tin, their neighbours in Devonshire and Somersetshire hired their pastures at a rent, and stored them with the cattle they brought from their own homes, and made a profit of the Cornish, by cattle fed at their own doors. The same persons also supplied them at their markets with many hundred quarters of corn, and horse-loads of bread." Borlase, in his observations on this passage, remarks, that "the people increasing, and the mines sometimes failing, the Cornish felt the necessity of applying themselves to husbandry; and their improvements answered their expectations; for, in the latter end of the reign of Queen Elizabeth, they found themselves in a capacity not only to support themselves, but also to export a great quantity of corn to Spain and other foreign parts." The agriculture of Cornwall is, notwithstanding, still but a secondary object. The portable commodities of the county are chiefly carried on the pack-saddle; and the hills and steep acclivities rendering the use of sure-footed animals necessary, the breeding of mules has been successfully attended to. Great numbers are employed in carrying the produce of the mines: the price of a good mule is frequently eighteen or twenty guineas. The common horses, though small, are hardy and well adapted to a hilly country. The vegetable soils are extremely various, but their general distinctive characters may be arranged under the heads, *black growan* or gritty, and the *shelly* or *slaty* soil. The former abounds in the high lands, the upper stratum chiefly consisting of a light black earth, intermixed with small gravel, the detritus of *granite* or *growan*, and hence the soil receives its appellation. This stratum, on the tops and sides of mountains, is very shallow, and not of considerable depth even on the more level and extensive wastes: its natural produce is a thin short heath, and the dwarf, or Cornish furze. A stratum of a cubical quartz is generally found beneath, of various sizes, and from four to eight inches thick; and below this a whitish or yellowish loamy clay. By digging up the quartz, and intermixing the under stratum of clay with the growan earth on the surface, a prolific soil is produced, fit for any kind of grass. The coasts of Cornwall abound with a great variety of fish; one species of which, the *pilchard*, is taken in sufficient quantity to constitute a considerable and productive branch of commerce. See *PILCHARD*.

"The sea," says Borlase, "is the great store-house of Cornwall, which offers not its treasures by piece-meal, nor all at once, but in succession: all in plenty in their several seasons, and in such variety, as if nature was solicitous to prevent any excess or superfluity of the same kind." In this author's "Antiquities of Cornwall," the numerous species of fish that visit this coast are particularly described. The sea-sands round Cornwall probably exceed in variety those of any other county in Great Britain; the sand of every cove being different. The sand of a particular shore, cove, or bay, has generally the same colour; and a microscope shews it to be of the same substance as the adjacent cliffs, and the strata under the sea. Clays are found in this

county in great variety, and many of them are eminently useful for different purposes of manufacture. The yellow clay, in St. Kevran's parish, is esteemed but little inferior to any, for casting in silver, brass, or lead; the yellow clay from Lannant is much valued for building furnaces, as the bricks made with it are supposed to have a peculiar faculty of withstanding intense heat.

The mineralogical substances of Cornwall are far more abundant than those of any district of the same extent in the world; and the scientific inquirer finds in their beauty and variety a proportionable field for his researches. Among the rocks claiming especial notice, is granite, or, as here called, *moor-stone*, of which this county affords more than any other part of England. It forms the chain of mountains, which, commencing at Dartmoor, runs through Cornwall to the sea at the Land's End, and to the northward and southward goes into primitive schistus. Granite is an aggregate of felspar, quartz, and mica; and the varieties found here are innumerable, both in the size and colour of its component parts. Between the town of Liskeard and the river Tamar are some quarries of slate; whence the inhabitants of Plymouth are supplied with covering for their houses, and for the purpose of exportation. The free-stone is of two sorts: one composed of sand and argil, the other of sand and quartz: that of the purest quality is found in the parishes of Carant and the Lower St. Columb, and approximates to the Portland and Bath stones. The Polrudon or Pentowan stone is likewise of a sandy nature: it lies in irregular masses of three different colours, in a shelving lode about 15 feet in width. A curious production, called the *swimming-stone*, has been discovered in a copper mine near Redruth; it is of a yellowish colour, and consists of quartz in right-lined laminæ, as thin as paper, intersecting each other in all directions, but leaving unequal cavities between them: this cellular structure renders the stone so light, that it swims on water, whence it obtained its name. Some beautifully transparent quartz are found here, crystallized in six-sided pyramids, with a correspondent hexagonal prism. That part of the county which forms the Lizard Point is composed of serpentine and hornblende of the most beautiful kind, including every shade of green, from pea-green to black, variegated by tints of purple and scarlet. The serpentine is occasionally intersected with veins of the *steatites*, so called from the Greek word for tallow, to which it has some similarity. But this curious substance is contained in the greatest abundance in the celebrated *soap-rock*, situated between the Lizard and Mullion: it is of whitish or straw colour, with veins of green, red, and purple. When embedded in its matrix, the serpentine, it feels wet, and may be compressed with the hand; but being exposed to the air, becomes indurated, and of a soapy texture. The whole soap-rock is rented by the proprietors of the porcelain manufactory at Worcester. It is remarkable, that letters written with soap-stone (*steatites*) upon glass, though insensibly fixed, are not to be moved by washing, but always appear on being moistened with the breath. Solid asbestos is often seen adhering to the pure specimens of the *steatites*, and is also spread, like a thin film of enamel, on the surface of some rocks exposed to the sea. The fibrous asbestos has been discovered in St. Cleer's parish, fixed to stones of the killas kind, and sometimes running through them in a wavy line. But the most important of Cornish fossils is the *china stone*, obtained in the parish of St. Stephen, near St. Austel, and forming a principal ingredient in the Staffordshire pottery. It is a decomposed granite, the felspar of which is deprived of fusibility. Its qualities were, about 40 years ago, discovered by chance, and it has since been an article of considerable

Corpach

CORPACH, in *Geography*, a small village in Argyle-shire, in Scotland, is about 2 miles nearly north from Fort-William, situate on the eastern shore of Loch Eil. This place cannot fail of obtaining celebrity in future, on account of the great works which are now carrying on for the western entrance-basins and locks of the great Inverness and Fort-William, or Caledonian, canal, intended to form a communication for large ships between the East and West seas, and avoid the large and often dangerous passage round the north of Scotland. The laborious operation of excavating, or rather hewing and blasting the hard rock, in which the locks at this place are to be built, was begun in July 1804; and, in December of the same year, the formation of two immense banks of earth, (nearly similar to those we have mentioned as constructing at the eastern entrance at CLACHNACARY) was begun to extend into Eil Loch, for surrounding and protecting the sea or entrance lock, which is to be formed where the surface of the rocky stratum of this district is 20 feet under the line of high water of ordinary neap tides, but where the rock shelves off, so that no cutting will be required at the tail of the rock, from whence the depth of water in the lock gradually deepens through 4, 5, 6, 7, 8, and 13 to 16 fathoms, at the distance of about three quarters of a mile. There is a projecting head of rock in this place, which will form the body of a pier to protect the tide-lock. The rise of those locks, which are to be constructed behind Corpach house, will bring the bottom of the canal upon the top of the stratum of rock; into which the lock, connecting with the first or sea-lock, will be cut 11 feet 9 inches, and the third lock will be cut 4 feet into the rock. For the space of a mile and quarter from these locks eastward, the cutting of the canal is level on Corpach Moss, in strong compact sandy gravel, under about two feet of peat-moss. According to the report of Mess. T. Telford and W. Jessop, the principal engineers in this important concern, which was ordered to be printed by the house of commons on the 2d June 1806, it appears, that an engine-house had been built, and one of Boulton and Watt's 20 horse steam-engines fitted up, for pumping the water from the foundations of the first and second locks at Corpach; where the side-walls of the third lock from the entrance of the canal had been built, to the height of 12 feet above the bottom, which is rock, requir-

ing no inverted arch upon it; the fore-bay was completed, and also the tail-bay, forming here, also, the fore-bay of the second lock; for these ingenious engineers have adopted the plan of placing the locks on this great canal in groups, and making the head-gates of one lock act as the tail-gates of the rest, as they do at Runcorn, on the duke of Bridgewater's canal. The mortar used in these works, is from the lime-stone of Linmore island, at the mouth of the bay of Lochyol in Argyleshire, and is found to be an excellent water cement, after being exposed to the tide during a winter. The bank which is to inclose the north side of the sea-lock, had been carried forwards from high water mark, a hundred and forty yards into the lock, and two rail-ways of eight hundred, and five hundred yards long, respectively, had been laid for conveying gravel to this sea-lock, and to the second and third locks, as well as rough quarry stones, for facing the outside of the bank, as it proceeds, and defending it from the surf of the lock. The timbers and piles have been prepared for forming a coffer dam at the extremity and within this bank, for putting in the foundations of the sea-lock.

The first aqueduct at this end of the canal at Bannavie, is finished, consisting of two arches, 9 feet wide, 10 feet high, and 252 feet long, this being the width of the canal and its banks in this place, constructed of stone quarried near the spot. The locks at Corpach are building with stone of good quality, quarried at Fallefern, about 2½ miles north of that place, on the eastern bank of Loch Eil. The second aqueduct at this end of the canal, over the long river at Strone, was commencing, consisting of a centre arch of 25 feet diameter, and two side-arches 10 feet wide each; these last being paved with stones on edge, are intended as road-arches for communication between the different sides of the canal, except perhaps during the height of the largest floods in this river. Great part of the cutting and banking for the canal between Corpach and Loch Lochy, was in hand or finished, but the grand chain of eight locks between Corpach Moss and Bannavie was not begun, or intended so to be, until the sea-lock and the other two locks at Corpach are completed, so as to admit the stone vessels to proceed thus far up the line, to discharge their cargoes for building these stupendous locks. See CANAL.

Cotton

COTTON, in *Commerce*, the soft and beautiful vegetable down which forms the covering or envelope of the seeds of the gossypium or cotton plant. It is the spontaneous production of three parts of the earth, and is found growing naturally in all the tropical regions of Asia, Africa, and America, whence it has been transplanted and become an object of cultivation in the southern parts of Europe.

It is brought to us from the West India islands, the Spanish, Dutch, and Portuguese settlements on the coast of South America, and the isles of Bourbon and Mauritius in the East Indies. Georgia, and the southern states of North America, also annually produce great and increasing quantities. The islands and shores of the Mediterranean have long supplied Europe, and within these few years, the privileged merchants of India have brought hither considerable quantities from Surat, Madras, and Bengal.

The cotton from these different quarters of the globe varies considerably in the colour, length, fineness, and strength of its fibre. It is the produce of several species and varieties of the gossypium, and without wholly adopting the hypothesis of Quatremere Disjouvai, we may admit, that difference of climate has considerable influence on the texture and quality of the cotton.

According to the observations of that gentleman, crowned by the Academy of Sciences of Paris, the produce of the countries immediately under, or nearest the equator, is to be considered as the type of excellence, and is distinguished by its fine silky fibre, the depth and peculiarity of its colour, and the height and permanency of the plant. In proportion as we recede from the equator, says our author, these strong marked characters disappear, the fibre becomes coarse, its colour perfect white, and on the shores of the Mediterranean, we behold the lofty and flourish-

ing tree of Hindoostan, dwindled down into a stunted annual shrub.

The exceptions to this system, from a comparison of the cotton of South America and the West Indies, with that of India and the Levant, are repelled by M. Quatremere Disjouvai with some ingenuity, but his observations and reasonings are too general; and we shall presently see that this system of gradation in size, colour, and fineness, from the equator to the poles, has no existence in nature, and is disproved by the characters we shall adduce of the principal varieties of cotton at present known in commerce.

It is true, that the finest cotton we have any knowledge of, is the produce of the tropical countries, as well as the deepest coloured. The delicate and unrivalled fabrics of the East, and the genuine nankeens of India and China, afford a proof of this. Yet the cotton from which they are produced, is retained at home to supply the native manufactures of the country, and is wholly unknown in commerce. The cotton of Bengal, Madras, and Surat, such as is brought in quantities to Europe, is scarcely tinged with yellow; and Siam, famous for its nankeen, is equally so for its fine white cotton, which has long been transplanted to the West Indies. The sea-coast of Georgia, and its dependant isles, though situated in latitude 33° north, ten degrees beyond the tropic, produces cotton superior in quality to the colonies of Guiana directly under the equator, whilst the inland districts of that province, and the country south of it, down to the mouth of the Mississippi, produce a cotton of greater whiteness, and far inferior in strength and fineness.

Cotton is distinguished in commerce by its colour, the length of its fibre, and its strength and fineness.

White is in general considered as characteristic of secondary

quality. The cotton of Smyrna, Cyprus, Salonica, and all parts of the Levant, is distinguished by its want of colour. The chief part of that from North America is also white, viz. New Orleans, Tennessee, and Upland Georgia.

Yellow, when not the effect of accidental wetting, or inclement season, is indicative of greater fineness. The cotton of the West Indies and of South America is called yellow, but the colour inclines more or less to cream colour. That from India has a slight tinge of Aurora. The fine Sea Island Georgia, though not properly a yellow cotton, has a faint but decided tinge, which distinguishes it from the white cotton of the same country.

In the following list are enumerated the chief, and nearly all the varieties of cotton used in this kingdom, with short notices of their quality and value.

North American Cotton.

Sea Island Georgia—is the produce of the coast of Georgia, and the small islands contiguous and belonging to it. It has a long and fine staple, but more or less silky, stained or dirty, on which account no other cotton varies so much in price. The best is preferred now to every other kind, and is often sold at very high prices to the manufacturers of lace.

Upland, or Bowed Georgia—is the produce of the inland districts, and either from the nature of the soil, or defective cultivation, is much inferior to the preceding. It is a light simpy cotton, of weak, and very unequal staple, having long and short fibres intermixed. It is used chiefly for inferior goods. It derives its name of Bowed Georgia from an instrument like a bow, which the planters use in cleaning it.

Tennessee—much like Bowed Georgia, but in general cleaner, and sometimes better staple.

New Orleans—this also resembles Bowed Georgia, but it is generally preferred both to that and Tennessee. The fibre of these three kinds is weak, compared with that of West India, or Sea Island, and goods manufactured from it, are unable to endure the same hardship.

South American Cotton.

Pernambuca—fine, long staple; clean and pretty uniform in quality; much esteemed; principally used by the hosiery.

Maranham—rather inferior to Pernambuca; not so even in quality, nor so clean; much like good Demarara, and used for the same purposes.

Babia—much like Maranham; sometimes it has the advantage.

Rio—a very inferior cotton; very brown; much shell in it; used generally for the same purposes as low West India.

Surinam—has a long staple; clean; yellow; it is a fine cotton, and much used for making stockings.

Cayenne—a fine good clean staple, preferable to Surinam.

Demarara—the quality of this cotton has fallen off since the colony has been in possession of the English. The best has a fine silky strong staple, much esteemed. The inferior sorts are rather brown, dirty, coarse, and much mixed.

Berbice—the quality of this has of late years fallen off. The best has a good staple, fine, silky, and clean; but latterly it is brown, dirty, and mixed.

Carthagena—has a very long staple, but weak; it is very strong, and rather dirty.

Giron—a brown coloured cotton, fair staple, and generally pretty clean.

Cumena—inferior to Giron, and not so clean.

Carraccas—inferior to Giron; still more dirty.

Laguira—inferior to Cumena, but preferable to Carracca; not so dirty.

West India Cotton.

Bahama—Cotton from the Bahama islands is of various qualities. The best is grown from Bourbon seed, but is much inferior to that kind. The staple is pretty good, fine and silky, but it is often dirty. The inferior Bahamas are very brown and dirty. The staple rather short but strong.

Barbadoes—is of fair middle quality, the staple not very long, but generally silky, and pretty strong; often a good deal of the shell of the seed in it, which is a great objection.

Jamaica—very little cotton grown here, and that of very inferior quality; there is the long staple, which is very weak, and often very dirty, and the short, which is also very poor and dirty.

St. Kitt's—very little grown; it is in general very brown, dirty, but of fair staple.

St. Lucia—the same.

St. Thomas—the same.

St. Domingo—sometimes very clean good cotton, and likewise very inferior; not much comes here.

Carriacou—rather a coarse grain, but in general clean, fair, strong staple, used by the hosiery to mix with fine cotton, such as Pernambuca.

Grenada—a good deal like Carriacou, but not always so clean.

St. Vincent's—rather high-coloured; clean, good staple, but not very fine; a good deal cultivated for the size of the island.

Antigua—very little grown, much like St. Kitt's.

Tortola, Montserrat, Dominica—the same.

Martinique—very little comes here. It is a fair middle quality.

Guadaloupe—much the same, sometimes very good cotton.

Tobago—little grown, sometimes very fair good cotton.

Trinidad—rather short staple, and in general very dirty.

East India Cotton.

Bourbon—the most even and uniform in quality of any other. It is a fine silky staple, and very clean. It is the most valuable cotton brought hither, except the best Sea Island.

Surat—has a fine, but exceedingly short fibre, in general dirty, containing leaf and sand. It is the lowest priced cotton in the market, and used in the manufacture of low coarse goods.

Bengal—much like Surat, but still shorter staple, in general cleaner, and much about the same value.

Madras—not much brought hither. It is mostly from Bourbon seed, and sometimes not unlike in staple, but in general dirty, and contains much shell, which renders it less valuable; worth little more than Surat; some very good will fetch the price of West India.

Turkey.

Smyrna, &c.—a short mossy kind, and rather dirty, used for making candlewicks; has more substance than Bowed Georgia.

The preceding observations are intended to give general ideas of the comparative value and qualities of the different kinds enumerated, rather than precise and accurate descriptions, which, from various causes, such as unfavourable

seasons, exhausted soil, defective management and culture, cannot, as may readily be supposed, constantly and invariably apply.

In estimating their commercial value, we may place them in the following order, which compared with the gradation of M. Quatremere Disjonval's system, presents a curious contrast.

Sea Island Georgia, Bourbon—Pernambuca—Cayenne, Bahia, Maranhon, Surinam—Demarara, Berbice—Bahama, Grenada, Carriacou, Barbadoes and best West India—Giron, and best Spanish, New Orleans, Smyrna—Jamaica, St. Kitt's, &c. &c., and inferior West India—Bowed Georgia, Carthagena, Carraccas, and inferior Spanish—Madras, Bengal, Surat.

The relative value of the cotton in the first half of this series, is tolerably permanent, and is here pretty accurately expressed. The varieties in the other half vary considerably. It is deduced from the average prices of the different kinds, during a period of several months.

It must be observed, however, that the low value of East India cotton from Surat, Bengal, and Madras, arises chiefly from the excessive shortness of its fibre, which, though fine and silky, unfits it for the manufacture of a fine thread by our mode of spinning, though we are assured the natives of Hindoostan employ it in the manufacture of their finest muslins.

The importation of cotton into Great Britain has progressively and rapidly increased during the last twenty-five years, as will appear from the following statements, from which some idea may be formed of the astonishing and unexampled increase and prosperity of our cotton manufactures during that period.

Importation of Cotton into Great Britain.

In the year 1781	5,101,920 lbs.
1782	11,206,810
1783	9,546,179
1784	11,280,238
1785	17,992,888
1786	19,151,867
1787	22,600,000
From 1786 to 1790	23,443,670 per an
In the year 1799	46,000,000
1800	56,010,732
1802	65,850,395
1806	75,000,000 *

* This year's importation is not given from official documents, and is not therefore to be relied on as strictly accurate.

London and Liverpool are the great marts for cotton, the chief part of which was for a long time imported into London, but the situation of Liverpool, in the very heart of the cotton manufactures of the north, has rendered it the principal market in the kingdom, and great part of the cotton belonging to the merchants of London is now consigned there.

The following is the number of bags, of about 300 lbs. each, imported into London and Liverpool in four different years, from which may be derived a tolerably accurate idea of the relative quantities of different kinds of cotton brought into this kingdom, and of the increased cultivation of some particular sorts.

Importation of Cotton into London.

	1798.	1799.	1805.	1806.
Hamburgh, Tonningen, &c.	7327	11208	514	137
Lisbon - - -	5661	17818	3020	7281
Oporto - - -	1095	2583	1373	1095
Gibraltar and Mediterranean	2748	752	1234	218
Charlestown and South Carolina	3079	3981	2113	3911
Philadelphia, Maryland, New York, &c.	2084	5172	469	1035
New Providence - -	1489	1911	1712	
Savannah - - -	1221	1514		40
Smyrna - - -	600	1208	54	1360
Guernsey - - -	531		162	5
Jamaica - - -	612	5003	366	639
Montferrat, St. Kitt's -	729	838	1735	2325
Bahama - - -	405			
Grenada - - -	2122	846	1577	2632
St. Domingo - - -	690			
Barbadoes - - -	1911	686	1362	792
Antigua, St. Vincent's, and Tobago, - - -	526	381		
Demarara - - -	2581	3540	5294	4920
Martinique and Tortola	652	802		
Dominica - - -	783			
Surinam - - -	72	448	5040	3758
Copenhagen and Baltic		2020	601	
Berbice - - -		192	2467	1458
	36918	60903	29093	31606

Importation of Cotton into Liverpool.

	1805.	1806.	1791.	1799.
America - - -	100,148	100,142	64	13,236
Lisbon - - -	36,739	33,646		
Oporto - - -	1958	1647		
Demarara - - -	9495	10981		
Berbice - - -	6715	5784		
Surinam - - -	3072	1139		
Barbadoes - - -	7995	5495		
Bahamas - - -	1634	1980		
Dominica - - -	775	1491		
St. Thomas - - -	1170	1743		
Antigua - - -	83	278		
Tortola - - -	1221	1325		
St. Lucia - - -	1288	1389		
St. Kitt's - - -	260	224		
St. Vincent's - - -	183	189		
Nevis - - -	29	72		
Grenada - - -	200	384		
Trinidad - - -	125	287		
Cuba - - -	175			
Montferrat - - -	24	10		
Jamaica - - -	2483	4011		
Bourbon - - -	588			
Spain - - -	608			
Ireland - - -	450	546	3871	1690
Tobago - - -		5		
Teneriffe - - -		306		
Holland - - -			1950	
Turkey - - -			2242	
	177,418	173,074	68,404	86,784

From these statements it appears, that in 1791, sixty four bags of cotton only were brought into the port of Liverpool from North America; 25,814 into London and Liverpool in 1799, and in 1806, upwards of one hundred thousand bags into Liverpool alone; nearly half the quantity imported into the whole kingdom of every description whatever.

The cultivation of cotton is become an object of principal concern, and is rapidly increasing in the southern states of North America. The produce of some parts of Georgia, as we have before observed, is of very superior quality; and there is every reason to believe, that in a few years, it will rival in quantity, as well as quality, the fine cottons of Brazil and Guiana.

It may not, perhaps, be irrelevant to our subject, to remark here, that the colonization of Georgia formed the subject of a memorial presented to the duke of Newcastle, then secretary of state in the reign of George I., by colonel John Parry, a native of Switzerland. In this memorial, which was afterwards published, he sets out with this postulate, that "there is a certain latitude on our globe, to happily tempered between the extremes of heat and cold, as to be more peculiarly adapted than any other for certain rich productions of the earth," amongst which he enumerates silk, cotton, indigo, &c.; and he fixes on the latitude of 33°, whether north or south, as the identical one for that peculiar character. He settled some years afterwards, with a colony of his countrymen, on the river Savannah, which parts Carolina from Georgia, where he perpetuated his name by founding the town of Parrysburg; and proved, in some degree, the truth of his system, by the introduction of those objects of cultivation, which have since become staple articles of the country.

The first importation of cotton from the East Indies took place in the year 1798. This cotton is not imported by the India company, but by the privileged merchants; and the first cargo brought by the *Fame*, and valued at 10,000*l.*, cleared the enormous sum of 50,000*l.* The cotton at that time sold at 2*s.* 2*d.* per pound, the following year it fell to 10*d.*, and is now the lowest priced cotton in the market.

The following is the amount of importations since that time.

Importation of East India Cotton.

1798	4637	Bales of about 350 lbs.
1799	19714	
1800	19820	
1801	12111	
1802	8900	
1803	10476	
1804	3546	
1805	1842	
1806	8422	

All cotton whatever is subject to a duty of 2*d.* per pound, and also of 1½ per cent. on that amount. Calculated at the prices of that article in 1803. The amount of the duty on each particular kind is as follows.

Sea Island Georgia	-	4 per cent. ad valorem
Fine Brazil	-	8
British West India	-	8½
Foreign West India	-	10
Inferior Brazil	-	12
Turkey	-	12
Bowed Georgia	-	12½
Spanish Cotton	-	15 to 23½

Cotton, as a vegetable substance, approaches in its nature nearly to the ligneous matter, or woody fibre, and affords, by destructive distillation, the same products, and nearly in the same proportions as the hard and heavy woods. It is distinguished by its great affinity for earths and metallic oxides, but more especially for alumine and iron, on which is founded the theory and practice of calico-printing.

It is little alterable, insoluble in water, and the chief part of the weaker reagents. Nitric acid converts it into various vegetable acids. Vitriolic acid acts upon it as on ligneous fibre, both are decomposed, charcoal developed, and sulphureous acid given out. It is also distinguished by the beauty and permanency of the white which it acquires by alternate exposure to the action of alkalies and atmospheric air, or oxygenated muriatic acid.

The structure of the fibres of cotton has not been well ascertained. Lewenhoeck, by microscopical examination, found them to have two sharp sides, and it seems to be owing to this circumstance, and to their possessing some asperities like the filaments of wool, that cotton greatly irritates and inflames wounds and ulcers, if applied to them instead of lint.

COTTON, in *Ancient Geography*, a town of Asia Minor.

COTTON-grass, in *Botany*. See ERIOPHORUM.

COTTON Manufacture, in *Commerce*, one of the leading and most important branches of our national industry and commerce.

The history of its progress during the last century, affords a splendid instance of the successful application of industry and talent to a branch of manufacture, unparalleled in the annals of commerce.

Scarcely fifty years have elapsed since it was amongst the humblest of our domestic arts, and was confined chiefly to the fire side and cottage of the labouring poor of Lancashire. Its products were few, and mostly for home consumption, though some articles from Manchester were exported above a century ago. Its processes were simple, and the contrivances for accelerating labour, such as had been handed down for ages past with little alteration. The population engaged in this manufacture about the year 1750, is supposed not to have exceeded 20,000, and was little more than doubled in the succeeding twenty years.

From this state of comparative insignificance, it burst forth at once with a vigour and activity which has no parallel, and from causes which we shall state hereafter, became in the short period of thirty years, one of the most flourishing and important branches of our national industry.

For our internal consumption, it affords a variety of fabrics, suited not only to the ordinary wants and comforts, but also to the elegancies of life; and for exportation, such now is our superiority, that there is scarcely a civilized nation on the earth, that is not indebted to us for some article of this manufacture, and well authenticated accounts have been published of their having been found as articles of dress amongst the distant tribes of Tartars.

In the following article we shall endeavour to trace the progress of this manufacture from its origin down to the present time, and the causes which have contributed so powerfully to raise it in a few years to a state of importance, little short of that which the great staple manufacture of this country, that of wool, has acquired during the five last centuries.

The period of its first introduction into this country is not clearly ascertained, and there are few authentic documents of earlier date than the middle of the seventeenth

century, before which time, it is probable that the manufacture of cotton was too inconsiderable to deserve much notice.

The first historical notice we meet with is in the Itinerary of Leland, who visited Lancashire in the reign of Henry VIII. "Bolton-upon-Moore market," says he, "standeth most by *cottons*, divers villages in the moores about Bolton do make cottons." From this an inference has been drawn in favour of the existence of the manufacture of cotton in Lancashire at this early period, a supposition which is however completely overturned by an act passed the 5th and 6th of Edward VI. 1552; entitled "for the true making of *woollen* cloth," in which it is ordered "that all the cottons, called Manchester, Lancashire, and Cheshire cottons, full wrought to the sale, shall be in length twenty-two yards, and contain in breadth three quarters of a yard in the water, and shall weigh *thirty pounds* in the piece at least. Also that all other cloths called Manchester rugs, otherwise named Manchester frizes, full wrought for sale, shall contain in length 36 yards, and in breadth three quarters of a yard, coming out of the water, and shall not be stretched on the tenter, or otherwise, above a nail of a yard in breadth, and being so fully wrought and well dried, shall weigh every piece 48 lbs. at the least." However paradoxical it may appear, it is nevertheless clear from this passage of the act, that the Manchester cottons of that day were a species of woollen cloth, and that of the coarsest and strongest kind, as is sufficiently proved by the weight required by the statute. The testimony of Camden also to this point is decisive: when speaking of Manchester in 1590, he says, "this town excels the towns immediately around it in handfomeness, populousness, *woollen manufacture*, market place, church and college, but did much more excel them in the last age, as well by the glory of its *woollen* cloths, which they call Manchester cottons, as by the privilege of sanctuary, which the authority of parliament under Henry VIII. transferred to Chester."

The manufacture of these cottons was known also in Wales, as appears from the 8th of Elizabeth, 1566; in which we have the following historical fact. "In the town of Shrewsbury there hath been, time out of mind of man, and yet is, a company, fraternity, or guild, of the art and mystery of drapers, which said fraternity hath by reason of a certain trade and occupation, of buying and selling of Welsh cloth and linen, commonly called *Welsh cottons*, frizes and plains, which they have had and used amongst them, been able not only to live thereby, but also have, at their common cost, provided houses and other necessaries for poor people within the said town of Shrewsbury." The distinction of the Welsh cottons here into frizes and plains, is another proof of their being made of wool.

It is certainly singular, that the term cotton should be applied to goods manufactured wholly of wool, and which from their weight and substance could not possibly be intended as imitations of, or substitutes for, the cotton goods of any other country.

The fact is however sufficiently evident from the preceding quotations, and still further from the consideration that at the present day the *Kendal cottons*, a manufacture which has subsisted now near five centuries, are made entirely of wool, and that of the coarsest kind.

Like the Welsh cottons they are manufactured both frized and plain; and are used chiefly for negro cloathing in America and the West Indies, though some are worn at home by the poor or labouring husbandmen. Various conjectures have been offered respecting the origin of the name, but the most probable is, that it is a corruption of the word

coating. However this may be, it is very certain that the Manchester, Cheshire, and Welsh cottons, which in all probability were derived from those of Kendal, were made entirely of wool, and that it is to these goods the observation of Leland applies in the quotation we have before given.

To whatever purpose cotton was applied, it is certain that long before we have any mention of the manufacture the raw material was imported into this kingdom. The earliest record we have met with, in a happy and not very extensive search, is preserved by the accurate and indefatigable Hackluyt in the first volume of his *Collection of Voyages*, and is contained in a little work entitled the "*Process of English Policy*." The intent of the whole poem (for such it is) is to inculcate the absolute necessity to our commerce and existence as a free state, of England keeping the dominion of the seas; but it is chiefly valuable for the list which it contains of the different natural productions, as well as manufactures, which were at that time the objects of commercial intercourse between the European states. After enumerating the various articles which constitute the trade of Spain, Flanders, Portugal, Britain, Scotland, Ireland, Prussia, Germany, Venice, Florence, Brabant, Holland, &c., he tells us, that "Genoa resorts to England in her huge ships, named Carracks, bringing many commodities, as cloth of gold, silk, paper, much woad, wool, oil, cotton, roach alum, and gold coin; and they bring back from us wool and woollen cloth made with our own wool." It is evident from the preceding quotation, that at least as early as 1430, about which time this little work was first printed, and probably also much earlier, this country was supplied by the Genoese with cotton from the Levant. The Genoese possessed this trade till the year 1511, when, according to Hackluyt, from that time to 1534, "divers tall ships of London and Bristol had an unusual trade to Sicily, Candia, and Chios, and sometimes to Cyprus and to Tripoli, and Baruth in Syria. They exported thither sundry sorts of woollen cloths, calf-skins, &c., and imported from thence silks, camblets, rhubarb, malmsey, muscadell, and other wines, oils, cotton-wool, Turkey carpets, galls, and India spices. The Levant trade was soon after engrossed by the merchants of Antwerp, and till 1575 entirely abandoned by the English. Wheeler, who wrote in 1601, says, that 'a little before the troubles in the Low Countries, the Antwerp-ians were become the greatest dealers to Italy, in English and other foreign merchandize, and also to Alexandria, Cyprus, and Tripoli in Syria, beating the Italians, English, and Germans entirely out of the trade, as they also soon did the Germans at the fairs and marts of their own country.' Accordingly we find from the same author, that cotton was one of the many articles with which they supplied this country at that period, which they brought chiefly from Sicily and the Levant, and sometimes from Lisbon, along with many other precious articles which the Portuguese derived at that time from India. After the sacking of Antwerp the English trade to the Levant revived, and in 1621 was in a flourishing state, as appears from the testimony of Mr. Munn, in his treatise on the trade of India, in which cotton is enumerated as one of the many articles brought by our merchants from the Mediterranean.

From these quotations it is evident, that previous to the discovery of America and the West Indies, and for some time afterwards, this country, and probably all Europe, was supplied with cotton from the Levant.

How far, from this early importation of the raw material, we have a right to infer the existence of a cotton manufacture in this kingdom, may perhaps admit of some dispute,

yet it is certainly very probable that, acquainted as we must have been in some degree with the cotton cloths of the East, and other countries, and furnished with the material for their fabrication, some attempts would be made to imitate them. One great use of cotton no doubt, at these early periods, was for candlewicks; and to whatever purpose else it was applied, the manufacture had made no great progress in this country till the beginning of the seventeenth century, nor does it appear that on the continent, from whence, till within these few years, almost all our manufactures of cloth have been derived, the manufacture of cotton had made any progress before the middle of the sixteenth century.

Fustians were first made in Flanders, if we may credit Guicciardini, in his history of the Netherlands, who however assigns no date to their first introduction. In the little work we have before alluded to, anno 1430, preserved in "Hackluyt's Collection of Voyages," they are mentioned not only as an article of export from Flanders to Spain, but of import also from the Easterlings, Prussia, and Germany. We are disposed to believe they were first manufactured in Italy, where, from its proximity to the countries affording cotton, as well as its earlier communication with those nations which supplied Europe with cotton cloths, it was more likely to originate, than in the more remote and northern states of the continent: and we learn also from Guicciardini, in another part of his work, that in 1560, Antwerp annually imported from Milan "great quantities of gold and silver thread, various wrought silks, gold stuffs, fustians and dimities of many fine sorts, scarlets, tammies, and other fine and curious draperies."

That the manufacture of fustian came originally to this country from the Netherlands is highly probable, and it is said to have been established in the towns of Bolton and Manchester by Protestant refugees. Fustians were manufactured there in the beginning of the seventeenth century, and it is probable their first introduction was not much earlier. Had the Flemish carried this manufacture to any great extent, it would have found its way to this country much earlier, from the vast number of weavers and manufacturers of every description that emigrated to England, from the time of Edw. III. down to the troubles in the Low Countries during the reign of Philip II. of Spain.

In one of the sumptuary laws of James I., passed in the parliament of Scotland in 1621, it is enacted, "that servants shall have no silk on their cloaths, except buttons and garters, and shall wear only cloth, fustians, and canvas of Scotch manufacture." This prohibition would seem to imply a very advanced state of the manufacture of these articles in Scotland.

The first authentic document concerning the cotton manufacture of this kingdom, is contained in Lewis Roberts' "Treasure of Traffic," published in the year 1641, and is as follows. "The town of Manchester buys the linen yarn of the Irish in great quantity, and weaving it, returns the same again in linen into Ireland to sell. Neither does her industry rest here, for they buy cotton wool in London that comes from Cyprus and Smyrna, and work the same into fustians, vermilions, and dimities, which they return to London, where they are sold, and from thence, not seldom, are sent into such foreign parts where the first materials may be more easily had for that manufacture."

The manufacture of linen cloth, properly so called, never we believe, constituted any great part of the trade of Manchester, but the fustians, and indeed all the cotton goods of that period, were made of linen warp, composed of Hamburg or Irish yarn, but chiefly of the latter, and these

probably formed great part of the linen goods which Mr. Roberts says were returned to Ireland.

Soon after this period, fustians were manufactured in quantities at Bolton, Leigh, and the places adjacent; but Bolton was the principal market for them where they were bought in the grey by the Manchester dealers, who finished and sold them in the country. The Manchester traders went regularly on market days to buy fustians of the weavers, each weaver then procuring his own yarn and cotton as he could, which subjected the trade to great inconvenience. To remedy this, the chapmen themselves furnished warps and cotton to the weavers, and employed persons in all the little villages and places adjacent, to deliver out materials, and receive back the manufactured goods when finished. Each weaver's cottage formed at that time a separate and independent little factory, in which the raw material was prepared, carded, and spun, by the female part of the family, and supplied woof, or weft, for the goods which were wove by the father and his sons.

The kinds of fustian then made were herring-bones, pillows for pockets and outside wear, strong cotton ribs and barragon, broad-raced linen thicksets and tufts, with whitened diaper, striped dimities and jeans. These were succeeded by cotton thicksets, goods figured in the loom, draw boys, and at later periods by cotton velvets, quiltings, counterpanes, corded dimities, velvets, velvetteens, and strong and fancy cords. It is scarcely possible to convey any adequate idea of the varieties of cotton goods that have issued from the loom, since the first dawn of this manufacture to the present time. The pattern cards of Manchester goods sent out to the continent by the leading houses engaged in the foreign trade, have presented specimens of near two thousand different kinds, varying in strength and fineness, from the coarse and heavy fabrics to the finest and most delicate muslins, and in colour from the richest chintz to plain and self-coloured grounds; some figured in the loom, some checked and others plain, yet all, or the greatest part of them, composed entirely of cotton.

For the introduction or improvement of many of these branches, this country is indebted to the late Mr. Willon of Ainsworth, near Manchester; originally a manufacturer of fustian. He early engaged in the manufacture of cotton velvets, which, by unwearied efforts, he brought to the utmost degree of perfection, and considerably improved the mode of dressing, finishing, and more particularly of dyeing, which at that time was very imperfect. His goods, especially his velvets, were finished in a style that acquired a high character, both at home, and in the foreign market, and were readily distinguished from those of any other manufacturer. He cleared off the loose and uneven fibres with razors, and burnt or singed them with spirits of wine. This mode was succeeded by the use of hot irons, in form somewhat resembling the weavers' drying iron, but rounder, which were first employed by Mr. Witlow: and at a later period by cylinders of cast iron heated to redness, over which the goods were evenly and rapidly drawn, and thus freed from that superfluous down, or pile, which they had acquired in the loom, or in the various operations of washing, bleaching, or dyeing.

Towards the middle of the last century, or soon afterwards, the manufactures above enumerated, or such of them as were then known, had become of great importance to the towns of Manchester and Bolton, affording various articles for home consumption, as well as for an increasing foreign trade, and giving employment to great part of the population of the surrounding country. They had arrived at that state at which a pause must naturally have ensued, and

beyond which they must have advanced with the slow and gradual increase of population; which, aided by every advantage, as well as by emigration from other districts, could never have kept pace with the demand, without the introduction of those improvements to which this country owes the prosperous and unrivalled state of its cotton manufactures, and of which we shall now proceed to give some account.

The mode of spinning in use in this country at that period was by the hand; on the well known domestic machine called a *one-thread wheel*. A single spindle put in motion by a wheel and band turned by the right hand, whilst the thread was managed by the left, composed the whole of this simple apparatus, on which one person could with difficulty produce a pound of thread, by close and diligent application, the whole day. The goods then manufactured were strong and coarse, compared with those of the present day, and little or no thread finer than from 16 to 20 hanks in the pound, each hank measuring 840 yards, was then spun. It was subject, as may readily be conceived, to great inequalities, its evenness depending greatly on the delicacy of touch, which the spinner by long habit had acquired, and varied with every little difference in the extension of the thread during twisting, and the revolution of the spindle in portions of the same length. As the demand for cotton goods increased, various contrivances were thought of for expediting this part of the manufacture. A patent was obtained by a person named Paul, and some others of London, for an engine for a more easy and expeditious mode of spinning cotton, and several other attempts were made at subsequent periods, but all with equal want of success, till the invention of the *Jenny*, by James Hargreaves, in the year 1767. Hargreaves was a weaver at Stanhill, near Church, a few miles distant from Blackburn, in Lancashire. He was a plain, industrious, but illiterate man, and possessed little mechanical skill or talent. He resided near the print ground, the first and infant establishment of the late Robert Peel, esq. from whose hints and conversation he derived much important assistance, and whose strong and active mind was at that time engaged in the promotion of every useful improvement connected with that branch of manufacture, in which he was afterwards so extensively concerned. An anecdote is still recorded in the neighbourhood, which ascribes to accident the parent of so many useful discoveries, the first invention of the *Jenny*. A number of young people were one day assembled at play in Hargreaves' house, during the hour generally allotted to dinner, and the wheel at which he or some of his family were spinning, was by accident overturned. The thread still remained in the hand of the spinner, and as the arms and periphery of the wheel were prevented by the framing from any contact with the floor, the velocity it had acquired still gave motion to the spindle, which continued to revolve as before. Hargreaves surveyed this with mingled curiosity and attention. He expressed his surprize in exclamations which are still remembered, and continued again and again to turn round the wheel as it lay on the floor, with an interest which was at that time mistaken for mere indolence. He had before attempted to spin with two or three spindles affixed to the ordinary wheel, holding the several threads between the fingers of his left hand, but the horizontal position of the spindles rendered this attempt ineffectual; it is not therefore improbable, that he derived from the circumstance above-mentioned the first idea of that machine which paved the way for subsequent improvement. It consisted at first of only 8 spindles, turned by bands from an horizontal wheel, in the centre of which was fixed a vertical shaft, with a handle at the top for the spinner. The threads passed between two horizontal pieces

of wood, the breadth of the machine, which, when pressed together, clasped fast the roving like the finger and thumb of the spinner, and were thus extended or drawn out. He had great difficulty in putting up the thread, or winding it on the spindle after twisting, which he at last accomplished by means of a treadle connected with a wire, and worked by the foot of the spinner. The *Jenny* in its original form was a rude machine. The first was made almost wholly with a pocket knife; and the clasp, by which the thread was drawn out, was the stalk of a briar split in two. It was, as may readily be conceived, defective in the construction of those parts essential to the performance of its work, and which an ordinary mechanic would have had no difficulty in contriving; but Hargreaves was obliged to work in secret, and possessing little mechanical skill, to avail himself of such assistance as he could procure, without making public the object he had in view.

Popular prejudice was soon excited against him, and the threats of his neighbours obliged him to conceal his machine for some time after it supplied the woof or weft for his own looms. It was, however, generally known that he had made a spinning machine, and his wife, or some of his family, having imprudently boasted of having spun a pound of cotton during a short absence from the sick bed of a neighbouring friend, the minds of the ignorant and misguided multitude became alarmed, and they shortly after broke into his house, destroyed his machine, and also part of his furniture. Hargreaves soon after removed to Nottingham, whither he was invited by the stocking weavers of that place, and where he assisted in the erection and management of a mill, about the time that Mr. Arkwright first settled there, after being in the same manner driven out, or rather deterred from settling in Lancashire, by the clamour and prejudice of the people. Hargreaves was little qualified, either by education or address, for the sphere of life into which he was removed, and after having assisted various persons in the construction of machinery, and communicated to each by turns the whole of what he knew, he died in poverty, ill requited by his employers, and little known to the country, which has since reaped such important benefits from his discovery. Before he quitted Lancashire, he had made one or two wheels of 12 or 16 spindles each for some of his relations or friends, and as the popular clamour abated, the number of these increased, till a second mob scoured the whole country and destroyed every machine, they could meet with. The value of this improvement however was so strongly felt, and the measures adopted against the ringleaders of this outrage so vigorous and decisive, that new wheels were immediately constructed, and it was remarked that many of those concerned in opposing their first introduction, were amongst the foremost to avail themselves of the advantages they now promised. Various alterations were made in the original machine, which from its form was inconvenient and tiresome to grown up persons, though girls of twelve or fourteen managed it with ease. The vertical wheel was substituted for the horizontal one, which rendered it much easier to work, and the treadle, which required an awkward and constrained posture, was rendered unnecessary by a simple contrivance managed by the hand. They were enlarged in their dimensions from twelve to twenty, and afterwards to thirty, fifty, and even eighty spindles, and their use rapidly extended over all the country, though their first introduction every where met with the most determined opposition. Even at Nottingham, if our information be correct, a serious affray took place on the first erection of the new machines, in which Hargreaves himself was severely wounded, and a young woman, who had accompanied him from Lan-

cashire, and had been accustomed to the management of his first Jenney, nearly lost her life.

To Hargreaves also is ascribed an improvement in the mode of carding, which, before his time, had been performed with hand cards, on the knee, a tedious and laborious operation. These were succeeded by stock cards, in which the lower card was fixed immovable on a stool or stock, which left both hands at liberty to manage the upper one. These were first used in the woollen manufacture, and introduced into Hargreaves' neighbourhood from Rosendale. His improvement consisted in applying two or three cards to the same stock, and suspending the upper cards, which from their weight and size would otherwise have been unmanageable, from the ceiling of the room by a cord passed over a pulley, to the other end of which was affixed a weight or counterpoise. With these, one woman could perform twice as much work, and with greater ease than she could do before in the common way.

The stock cards were succeeded soon after by cylinder cards, the invention of which is claimed by so many different persons, that it is impossible now to determine to whom the merit is due. Amongst the first who employed them, was the late Mr. Peel, who constructed a carding engine with cylinders at Blackburn, as early as the year 1762, in which he was assisted by Hargreaves.

Mr. Peel's engine consisted of two or three cylinders, covered with cards, but had no contrivance for stripping, or taking off the carded cotton. This was performed by two women with hand cards, who alternately applied them to the last, or finishing cylinder, and thus took off the carding by turns. This was, in all probability, the first carding machine that was made; but Mr. Peel's other avocations not permitting him to pursue the subject at that time, it was laid aside, and some years elapsed before it was improved and perfected by other hands.

Notwithstanding the severe punishment of the ringleaders of the last outrage, and the friendly means adopted to convince the labouring class of the folly and injustice of opposing these improvements, by which not only the country, but themselves, would in the end be so materially benefited, considerable alarm and uneasiness were again excited, and though no scarcity of work had been experienced, a belief universally prevailed, that all manual labour would soon be annihilated by the use of these new machines. A third and more numerous mob therefore assembled in the year 1779, by which all the machinery turned by water or horses, both for carding and spinning, and all the Jennies above a certain size, that could be found within eight or ten miles of Blackburn, were completely destroyed. Jennies of twenty spindles, or under, were alone respected, every machine turned by water was demolished, and the large Jennies were either cut into two small ones that came within the size prescribed, or if the owner chose, into one of twenty spindles, by sawing off the extra number which was often consigned to the flames. These and similar disturbances in different parts of the country impeded for an instant, but could not arrest the progress of this manufacture. Mr. Peel, whose machinery at Altham was totally destroyed and thrown into the river, and whose personal safety was oftentimes in danger from the fury of a licentious and ungovernable mob, retired in disgust from the country, and established a cotton mill at Burton in Staffordshire, on the banks of the Trent, where he continued to reside many years afterwards.

Soon after the invention of the Jenney in 1767, Sir Richard, at that time Mr. Arkwright, brought forward his improvement in spinning, on which he had been long

and laboriously engaged. This distinguished character, whose perseverance and invention raised him from one of the most humble occupations in society to affluence and honour, was the youngest of thirteen children, and was born in the year 1732, at Preston, in Lancashire. In this neighbourhood was then carried on a considerable manufacture of linen goods, and linen and cotton mixed, the various operations of which he had an opportunity of becoming intimately acquainted with, and being a man of uncommon natural powers, he directed his thoughts to the improvement of the mode of spinning, which had probably been conducted for ages by the same process. The first hint for effecting this improvement, he accidentally received from seeing a red-hot iron bar elongated, by being passed through iron rollers. Between this operation and that of elongating a thread, as now practised in spinning, there is no mechanical analogy; yet this hint being pursued, has produced an invention, which, in its consequences, has been a source of national and individual wealth unparalleled in the annals of the world.

The difficulties which Mr. Arkwright experienced before he could bring his machine into use, even after its construction was sufficiently perfect to demonstrate its value, would perhaps for ever have retarded its completion, if his genius and application had been less ardent.

His circumstances were by far too unfavourable to enable him to commence business on his own account, and few were willing to risk the loss of capital on a new establishment.

Having at length, however, had the good fortune to secure the co-operation of some persons who saw the merit of the invention, and were willing to assist his endeavours, he obtained his first patent for spinning by means of rollers in the year 1769, and to avoid the inconvenience of establishing a manufacture of this kind in the heart of the cotton manufacture, such as it then existed, he removed to Nottingham. Here, in conjunction with his partners, he erected his first mill, which was worked by horses, but this mode of procedure was found to be too expensive, and another mill on a larger scale was erected at Cromford in Derbyshire in the year 1771, the machinery of which was put in motion by water.

This patent right was contested about the year 1772, on the ground that he was not the original inventor. He obtained a verdict however, and enjoyed the patent without further interruption to the end of the term for which it was granted.

As the essential part of Mr. Arkwright's machine was entirely new, and was applied with the happiest success in various other forms for preparing the raw material for spinning, of which we shall speak hereafter, we shall pause a while in the historical detail of these inventions, and explain the general principles of its construction, and the mode in which its operation was performed. Previous to the year 1767, as we have already observed, all the spinning was performed on the domestic one-thread wheel, of which there were two kinds. The first, which we have before described, required the raw material to be previously prepared and carded, and was used for wool and cotton. The cardings were soft and loose rolls of the thickness of a candle, and from eight to twelve inches long, possessing little strength or tenacity, the slightest force being sufficient to break or pull them asunder. One end of this roll being held between the finger and thumb of the spinner, and the other twisted round the point of the spindle, was rapidly drawn out during its revolution, and formed a coarse soft thread called a *roving*. For coarse woollen goods, this operation was suf-

ficient, and the thread was ready for the loom, but for flax cloth, and more especially for cotton, this operation of *twisting* and *drawing* was repeated, and the roving was converted into a smaller, firmer, and longer thread. To this last operation, the term *spinning* was more particularly applied, the first being considered as preparatory, and was generally denominated *roving*. For some time after the introduction of the Jenney, this mode of roving on the single spindle continued in use, the joining of the short rolls or cardings, rendering manual dexterity absolutely necessary.

The second mode of spinning was on the flax wheel, and used for those substances, whose fibres from their nature, but more particularly from their length, would not admit of the preparatory process of carding. Their fibres were dressed and disposed in an even and parallel direction, by an operation resembling *combing*, and were then coiled round the head of the distaff, affixed to a wheel furnished with a spindle, bobbin, and fly. The fly and spindle moved together, and were kept in rapid motion by a wheel and band, worked by the foot of the spinner. The bobbin which received the thread, ran loose upon the spindle, and moved only by the friction of its ends, in proportion as the fibres of the flax were disengaged from the distaff, by the finger and thumb of the spinner, and were twisted by the fly. If we suppose the machine itself to be left at liberty, and turned without the assistance of the spinner, the twisted thread being drawn inwards by the bobbin, would naturally gather more of the material, and form an irregular thread, thicker and thicker, till at length the difficulty of drawing out so large a portion of the material as had acquired the twist, would become greater than that of snapping the thread, which would accordingly break. It is the business of the spinner to prevent this, by holding the material between the finger and thumb, and by separating the hand during the act of pinching, that the intermediate part may be drawn out to the requisite degree of fineness previous to the twist.

To accomplish these ends by machinery, the object of Mr. Arkwright's invention, two conditions became indispensably necessary. 1st. That the raw material should be so prepared as to require none of that intellectual skill, which is capable of separating the knotty or entangled parts as they offer themselves. And 2dly. That it should be regularly *drawn out* by certain parts resembling the finger and thumb of the spinner. The first of these was completely fulfilled by the various machines and contrivances for the preparation of cotton for spinning, which sir Richard afterwards invented and obtained a patent for; the second was accomplished in his first and capital machine, since called the Twist, or Water Frame.

The contrivance for *drawing out* the thread constituted the great merit of the invention, the fly, bobbin, and spindle connected with it, being derived with little alteration from the flax wheel before described. It consisted of a pair of cylinders, slowly revolving in contact with each other, at a little distance from a second pair revolving with greater velocity, the lower cylinder of each set being furrowed, or fluted, in the direction of its length, and the upper ones neatly covered with leather to enable them to hold the thread. If we suppose the end of a roving, or loosely twisted thread, to be passed through the first pair only, it may readily be imagined that it will be gradually drawn off the bobbin, and pass through the cylinders without suffering any other sensible change in its form or texture, than a slight compression from the weight of the incumbent cylinder. But if from the first pair it be suffered to pass immediately to the second, whose surfaces revolve much quicker, it is

evident that the quicker revolution of the second pair, will *draw out* the cotton, rendering it thinner and longer, when it comes to be delivered at the other side. This is precisely the operation which the spinner performs with his finger and thumb, and the application of this simple and beautiful contrivance to the spindle and fly of the common flax wheel produced that machine for which Mr. Arkwright's first patent was obtained, and which laid the foundation of all his subsequent discoveries.

Soon after the erection of his mill at Cromford, Mr. Arkwright made many improvements in the mode of preparing the cotton for spinning, and invented a variety of ingenious machines for effecting this purpose in the most correct and expeditious manner; for all of which he obtained a patent in the year 1775.

The validity of this second patent was tried in the court of King's Bench, in the year 1781, and a verdict was given against him on the ground of the insufficiency of the specification, but on the 17th of February 1785, in the court of Common Pleas, before lord Loughborough, the question was again tried, and he obtained a verdict, having established by evidence the sufficiency of the specification.

This verdict, in consequence of great numbers having engaged in the erection of machines during the interval of four years that had elapsed since the former decision, occasioned considerable alarm, and raised up a host of enemies, from whom a premium on each spindle was demanded, under the threat of immediate suit. An association was formed of the manufacturers principally concerned in the business, and another cause instituted by writ of *scire facias*, was tried before judge Buller in the court of King's Bench, on the 15th of June 1785, in which, after a very long trial, he was cast on the ground of his not being the original inventor.

Conscious that this was not the case, he moved in the court of King's Bench, on the 10th of November 1785, for a new trial; stating that, not being aware of the nature of the evidence to be brought forward on this trial for the first time after so many years had elapsed, he was then unprepared, but was now able to substantiate by proofs the falsity of great part of the evidence which went to that point. The rule however was refused, and on the 14th November 1785, the court of King's Bench gave judgment to cancel the letters patent.

The inventions claimed by Mr. Arkwright, which gave rise to these reiterated contests with the rival manufacturers of Lancashire, related chiefly to the operation of carding, which was now brought to great perfection. Before we enter however into any account of these improvements, it will be necessary to take a short view of the nature of this operation, and the mode in which it was performed at the date of Mr. Arkwright's second patent.

The *card* is a kind of brush made with wires instead of hair, stuck through a sheet of leather; the wires not being perpendicular to the plane, but all inclined one way in a certain angle.

From this description, such as are totally unacquainted with the subject, may conceive that cotton, being stuck upon one of these cards or brushes, may be scraped with another card in such a direction, that the inclination of the wires may tend to throw the cotton *inwards*, rather than suffer it to come out. The consequence of the repeated strokes of the empty card against the full one, must be a distribution of the cotton more evenly on the surface, and if one card be then drawn in the *opposite* direction across the other, it will, by virtue of the inclination of its wires,

take the whole of the cotton out of that card, whose inclination is the contrary way.

In this mode, the operation of carding was formerly performed by hand with sheets of card nailed upon thin boards, which were drawn and scraped against each other, till the cotton or wool was evenly diffused over the surface, and freed from all the knotty or entangled parts. One of the cards being then turned and applied in an inclined position, so as to scrape with one edge over the surface of the other card, in the direction of its teeth, the cotton was, by a particular manœuvre, stripped off and coiled up into those short soft rolls which we have spoken of already under the name of *cardings*. Such, in all probability, was the process employed with little alteration, during the five last centuries in the woollen manufacture of this kingdom, and applied at subsequent periods to the preparation of cotton. The use of cards was most likely derived from the Netherlands, at or before the time our woollen manufactures were improved by the emigration of Flemish weavers to this country, during the reign of Edward III.

They continued to be imported hither till the year 1463, when the tradesmen and manufacturers of London, and other parts of England, having made heavy complaints to parliament of the obstruction to their own employment by the introduction of various foreign manufactured wares, an act was passed in the third year of Edward IV., prohibiting *wool-cards*, and various other articles of iron, steel, copper, &c. from being imported into this kingdom.

The hand-cards were succeeded by stock-cards, and these again by cylinder cards, as we have already observed, which were first attempted about the year 1763.

This machine consisted of two or more large cylinders covered with cards, revolving in opposite directions, and nearly in contact with each other, and surmounted by other smaller cylinders covered in like manner, by whose revolutions in various directions, and with different velocities, the cotton was carded and delivered to the last or finishing cylinder, from which it was stripped off by different contrivances. The cards were nailed on in stripes, or sheets of six or eight inches broad, and the margin of each sheet in which the nails were driven, being destitute of teeth, formed so many intervals or furrows across the surface of the cylinder.

The cotton was stripped off first by hand, as in Mr. Peel's machine, and afterwards by a fluted cylinder, or by a roller armed with slips of tin-plate or iron, standing erect like the floats of an undershot wheel, and which revolving quicker than the card, and in close contact with it, scraped off the cotton in distinct portions from each stripe or sheet, which fell into a receptacle below. This was a harsh and rude operation, and rubbed and injured not only the carding, but the cards themselves. Mr. Arkwright substituted for the fluted cylinder a plate of metal finely toothed at the edge, and moved in a perpendicular direction rapidly up and down by a crank.

The slight, but reiterated strokes of this comb, acting on the teeth of the cards, detached the cotton in a fine and uniform fleece. On the finishing cylinder also, narrow fillet-cards, as they are termed, wound round in a spiral form, were substituted for the ordinary cards nailed across.

The *continuity* of the fleece was thus preserved, which was destroyed before by the intervals or furrows we have alluded to, and being gradually contracted in its size, by passing through a kind of funnel, and flattened or compressed between two rollers, was delivered into a tin can in one *continuous, uniform, perpetual carding*, so long as the machine

continued in motion, and was supplied with the raw material.

This is, without exception, one of the most striking and beautiful operations in the whole process of spinning. Mr. Arkwright's right to the invention of the crank and comb was the disputed point at the last hearing of this cause, and the evidence which he was unprepared to meet having proved to the satisfaction of the jury, the prior claim of a mechanic, named Heyes, his exclusive right, not only to this improvement, but to all others included in the same patent, was cancelled by the judgment of the court. How far Mr. Arkwright would have been able in the event of another hearing to have disproved the evidence thus unexpectedly brought forward, is not easy to determine. That the crank had been applied in some way or other, prior to the date of Mr. Arkwright's patent, though in a much less efficacious and approved manner, we believe will admit of the fullest proof, and this circumstance, in a case in which the interest of a great body of manufacturers was deeply concerned, and was opposed only by that of a single individual, would, in all probability, have confirmed the former decision in a court already weary of the discussion.

The improvement, as far as Mr. Arkwright was concerned, was original, and undoubtedly his own, and bears evident marks of that genius and happy invention which so strongly characterize every part of his machinery. He was anticipated in a single idea before it was matured and brought forth, and in this instance lost the fruits of his industry and talents. His claim to the spiral cards, which produce the endless, or perpetual carding, has however never been disputed. At the same time Mr. Arkwright brought forward other machines peculiarly adapted to the preparation of the materials for his own mode of spinning, and founded on the principle of his former invention. The first of these, in the series of successive operations, is the *drawing frame*.

This machine consists of a system of rollers similar to those before described in the twist frame, revolving with different velocities, either from the variation of size in the pairs of rollers, their performing a different number of revolutions in the same space of time, or from both these causes united. Three or more cardings coiled up in deep tin cans are applied at once to these rollers; in their passage through which, they not only coalesce so as to form one single *drawing*, but are also drawn out or extended in length. This process is several times repeated; three, four, or more drawings, as they are now termed, being united and passed between the rollers; the number introduced being so varied, that the last drawing may be of a size proportioned to the fineness of the thread into which it is intended to be spun. By this operation, the fibres of the cotton are drawn out longitudinally, and disposed in an uniform and parallel direction, and all inequalities of thickness are done away by the frequent doubling or joining of so many different lengths.

A third machine was contrived by Mr. Arkwright for giving the necessary degree of twist to these prepared lengths of cotton. In the state in which it comes from the drawing frame, it has little strength or tenacity, and is received into similar deep cans, from whence it was passed through the rollers. To enable it to support the operation of winding, it is again passed through a system of rollers similar to those in the last machine, and received in a round conical can revolving with considerable swiftness. This gives the drawing a slight twisting, and converts it into a soft and loose thread, now called a roving, which is wound by the hand upon a bobbin, by the smaller children of the mill, and then carried to the spinning or twist frame, of which we have already spoken.

Such are the inventions and improvements for which we are indebted to the genius of Mr. Arkwright, and which complete a series of machinery, so various and complicated, yet so admirably combined and well adapted to produce the intended effect in its most perfect form, as to excite the admiration of every person capable of appreciating the difficulty of such an undertaking. And that all this should have been accomplished by the single efforts of a man without education, without mechanical knowledge, or even mechanical experience, is most extraordinary, and affords a striking instance of the wonderful powers displayed by the human mind, when its powers are steadily directed to one object.

Yet this was not the only employment of this eminent man, for at the same time that he was inventing and improving the machinery, he was also engaged in other undertakings, which any person, judging from general experience, must have pronounced incompatible with such pursuits. He was taking measures to secure to himself a fair proportion of the fruits of his industry and ingenuity; he was extending the business on a large scale; he was introducing into every department of the manufacture a system of industry, order, and cleanliness, till then unknown in any manufactory where great numbers were employed together, but which he so effectually accomplished, that his example may be regarded as the origin of almost all similar improvements.

When it is considered, that during this entire period he was afflicted with a grievous disorder (a violent asthma) which was always extremely oppressive, and threatened sometimes to immediately terminate his existence, his great exertions must excite astonishment. For some time previous to his death, he was rendered incapable of continuing his usual pursuits, by a complication of diseases, which at length deprived him of life, at the Rock House, Cromford, on the 3d of August 1792, in the 60th year of his age.

The honour of knighthood was conferred on him in December 1786, on the occasion of presenting an address to his majesty.

In the infancy of the invention, sir R. Arkwright expressed ideas of its importance, which to persons less acquainted with its merits appeared ridiculous, but he lived long enough to see all his conceptions more than realized in the advantages derived from it, both to himself and his country; and the state to which those manufactures dependent on it have been advanced since his death, makes all that had been previously effected appear comparatively trifling.

The system of spinning introduced by sir Richard was found most particularly applicable to the production of thread for warp, whilst the Jenney of Hargreaves was chiefly employed in spinning the woof, or weft, for the coarse kinds of which it was better adapted, indeed, than the more perfect machine of sir Richard.

On these machines were spun, for some years after their introduction all the twist and weft in the kingdom; the use of the Jenney has, however, since been almost wholly superseded by a third machine, called a Mule, for the invention of which we are indebted to the ingenuity of Mr. Samuel Crompton of Bolton.

The mule was invented about the year 1776, during the term of sir Richard's patent right, and did not on that account come into general use till after its expiration. It is a compound of the two machines of Arkwright and Hargreaves, and is considered, as its name imports, as the offspring of the twist frame and Jenney. It consists of a system of rollers like those of the twist frame, through which the roving is drawn and received upon spindles,

revolving like those of the Jenney, and from which it acquires the twist. The carriage on which the spindles are disposed is moveable, and receding from the rollers somewhat quicker than the thread is delivered, draws or extends it in the same manner as is done by the Jenney. See MULE.

This completes the series of machines now in use, and is the only important discovery in spinning since the invention of sir Richard Arkwright, on which indeed its chief merit is founded.

Of its excellence, and also of those other machines employed in the different preparatory processes, some idea may perhaps be formed, when it is stated that a pound of fine cotton has been spun on the mule into 350 hanks, each hank measuring 840 yards, and forming together a thread 167 miles in length.

Hitherto we have entered only into such details of the different processes of spinning as were necessary to elucidate the history of their invention, and exhibit both the sources and progress of the various improvements.

The operations which cotton undergoes in its passage from the raw material to the state of thread, are various and multiplied in proportion to the fineness required, and the different uses to which it is destined.

If we analyze these operations, they resolve themselves into the following: Batting, carding, doubling, drawing, and twisting. The three latter are never performed singly, but are variously joined in the same machine; and the same elementary processes are oftentimes repeated in different machines, with various and different effects.

With reference to these effects, the operations which cotton undergoes, may be denominated batting, carding, drawing, and doubling, roving, and spinning.

Batting, is that operation which prepares the cotton for carding, by opening and disengaging the hard compressed masses, in which it comes from the bales.

It is performed by beating the cotton with sticks on a square frame, across which are stretched small cords, about the thickness of a goose quill, with intervals sufficient to suffer the feed, leaves, and other adventitious matter to fall through.

When a hard matted or compressed mass of cotton is smartly struck with a stick, the natural elasticity and resiliency of its fibres, gradually loosen and disengage them, and the cotton recovers by repeated strokes all its original volume. During this operation the seeds, &c. which adhere, are carefully picked out by the hand, and the cotton rendered as clean as possible.

Batting is generally and best performed by hand, though the scarcity of hands and cost of labour have rendered other contrivances necessary. For a description of the batting machine, with other particulars relative to this operation, see MACHINE.

Carding, is that operation in which the first rudiments of the thread are formed. It is performed, as we have before stated, by cylinders covered with wire cards, revolving with considerable swiftness in opposite directions, nearly in contact with each other, or under a kind of dome or covering, the under surface of which is covered with similar cards, whose teeth are inclined in a direction opposite to those of the cylinder.

By this means the separation of almost every individual fibre is effected, every little knotty or entangled part disengaged, and the cotton spread lightly and evenly over the whole surface of the last or finishing cylinder, from which it is stripped by the contrivance we have already described.

For Jenney spinning, which is still in use for the coarser

kinds of thread, the cardings are stripped off in separate lengths. The finishing cylinder is covered with the ordinary cards nailed on in stripes across, and the cotton contained between the margins or intervals of each stripe, forms one carding, whose length of course depends on the width of the engine, or cylinder. When stripped off by the crank and comb, it forms a loose and shapeless film, which falling on the surface of a plain wooden cylinder, the lower half of which revolves within a hollow shell or casing, the cotton in its passage is rolled up and delivered at the other side in perfect and cylindrical cardings.

For mule or water spinning, the finishing cylinder is covered with spiral or fillet-cards, and the cotton being taken off in one continued fleece, and contracted by passing through the funnel and rollers, forms one endless and perpetual carding, which is interrupted only, or broken, when the tin can that receives it is completely filled.

In the Jenney carding, the fibres of the cotton are disposed across or at right angles to the axis of the carding; in the perpetual carding they are disposed longitudinally, or in the direction of its length, and it is this circumstance which renders the carding destined for mule or water spinning, inapplicable to the Jenney, and *vice versa*. For further details, and a description of the carding engine, we must refer our readers to the article **ENGINE**.

Drawing, and *Doubling*, is one of the preparatory processes for which we are indebted wholly to Sir Richard Arkwright, and belongs exclusively to the mule, or water spinning.

The doubling, or passing three or four cardings at once through a system of rollers, by which they are made to coalesce, is intended to correct any inequalities in the thickness of the cardings, and also to admit of their being frequently drawn out or extended by passing through the rollers. The effect of this frequent drawing is to dispose the fibres of the cotton longitudinally, and in the most perfect state of parallelism. The operation of carding effects this in a certain degree; yet the fibres, though parallel, are not straight but doubled, as may easily be supposed from the teeth of the cards catching the fibres sometimes in the middle, which become hooked or fastened upon them. Their disposition is also farther disturbed by the taker-off or comb, which strips them from the finishing cylinder; and though the general arrangement of the fibres of a carding is longitudinal, yet they are doubled, bent, and interlaced in such a way, as to render the operation we are now speaking of absolutely necessary.

When the cardings have been passed four or five times through the drawing frame, every fibre is stretched out at full length, and disposed in the most even and regular direction; and though the average length of a fibre of cotton is not two inches, yet the finished drawing, as these prepared cardings are now termed, has all the appearance of a lock of Jersey wool, whose fibres, six or eight times as long as those of cotton, have been carefully and smoothly combed.

Roving, is that operation by which the prepared cotton, as it comes from the carding engine, or drawing frame, is *twisted* into a loose and thick thread, and wound upon a spindle or bobbin.

In Jenney spinning, the cardings are roved without any other preparation, by a machine called a roving billy, for a description of which, with other particulars relative to Jenney spinning, see **JENNEY**.

In mule or twist spinning, the prepared carding or drawing, as it is termed, is again passed through a system of rollers, and is twisted, either by a rapidly revolving can, into

which it is delivered from the rollers, or by a fly and spindle similar to those of the flax wheel; in the latter case it is wound on the bobbin by the machine; in the former it is received in the conical can in which it acquires the twist, and is afterwards wound upon bobbins by the smaller children of the mill.

Sir Richard Arkwright always employed the revolving can, and it is still employed in many of the first mills in the country. The roving frame with fly and spindle, which is in fact nothing more than the twist frame of Sir Richard, is now however very generally in use, especially since later improvements have removed objections to the machine, which rendered its use heretofore inconvenient. See **FRAME**.

The operations through which the thread passes after it has received the first twist are various, and depend greatly on the use it is intended for.

The finer it is required, the oftener it is drawn out and twisted, till by degrees, as in the process of wire-drawing, it is brought down to the fineness required. The rovings are therefore distinguished into first, second, and third, according to the number of operations they have gone through.

Spinning, is the last operation which the thread undergoes in the series of processes employed in converting it into thread, and is that in which it receives the final extension and twisting.

It is performed either on the Jenney, twist frame, or mule. Of these machines we have already spoken generally, and also of the nature of their operation; for further and more particular details, we must refer our readers to their proper heads.

Such are the operations by which the raw material is brought into the state of thread, and such the improvements by which the cotton manufacture of this kingdom has arrived at its present unexampled state of prosperity. We cannot give our readers a better idea of the effects immediately resulting from these various improvements and discoveries, than by the following extracts from a pamphlet, published in the year 1788, intitled, "An important Crisis in the Calico and Muslin Manufactures of this Country explained;" the purport of which was to warn the nation of the bad consequences which would result from the rivalry of the East India cotton goods, which then began to be poured into the market in increased quantities, and at diminished prices.

The author asserts, that, not above 20 years before the time of his writing, the whole cotton trade of Great Britain did not return 200,000*l.* to the country for the raw material, combined with the labour of the people; and at that period, before the introduction of the twist frame and Jenney, the power of the single wheel could not exceed 50,000 spindles:

In 1787, the number of cotton mills, as near as intelligence could be procured, was as follows:

In Lancashire	41	Flintshire	3
Derbyshire	22	Pembrokeshire	1
Nottinghamshire	17	Lanarkshire	4
Yorkshire	11	Renfrewshire	4
Cheshire	8	Perthshire	3
Staffordshire	7	Edinburghshire	2
Westmorland	5	Rest of Scotland	6
Berkshire	2	Isle of Man	1
Rest of England	6		

The whole being 143, the cost of which was estimated at - - - £ 715,000
 There were at the same time 550 mules, and 20,700 Jennies, containing, together with the water frames, 1,951,000 spindles; the cost of which, and of the auxiliary machine y, together with that of the buildings, is stated to have been at least - - - 285,000

The total expenditure being £ 1,000,000

These establishments, when in full employment, were estimated to produce as much cotton yarn as could be spun on the single spindle by a million of persons; and instead of diminishing the employment of the people as was apprehended, they called vast numbers from idleness to comfortable independence. At this time they were supposed to give employment to 26,000 men, 31,000 women, and 53,000 children in spinning alone; and in all the subsequent stages of the manufacture the number of persons employed, was estimated at 133,000 men, 59,000 women, and 48,000 children, making an aggregate of 159,000 men, 90,000 women, and 101,000 children, in all 350,000 persons employed in the different branches of the cotton manufacture.

The quantity of the raw material consumed in this manufacture, which in 1781 did not amount to 6,000,000 lbs., in the year 1787 exceeded 22,000,000. The astonishing rapidity of this increase, which will be more clearly shewn by the following statement, is to be in a great measure attributed to the extension of the manufacture to the goods of India, particularly calicoes and muslins.

Cotton used in the Manufactures of Great Britain.

Years.	Pounds.	Supposed value when Manufactured
1781	5,101,920	£ 2,000,000
1782	11,206,810	3,900,000
1783	9,546,179	3,200,000
1784	11,280,238	3,950,000
1785	17,992,888	6,000,000
1786	19,151,167	6,500,000
1787	22,600,000	7,500,000

The cotton imported for the manufacture of 1787, was of the following growth:

British West India, estimated at	6,600,000 lbs.
French and Spanish settlements	6,000,000
Dutch Settlements	1,700,000
Portuguese ditto	2,500,000
East India, procured from Ostend	0,100,000
Smyrna and Turkey	5,700,000
	22,600,000

The application of this cotton to the different branches of manufacture was supposed, by intelligent persons, to have been as follows:

Candlewicks	-	1,500,000 lbs.
Hosiery	-	1,500,000
Silk and Linen mixtures	-	2,000,000
Fustians	-	6,000,000
Calicoes and Muslins	-	11,600,000
		22,600,000

In the branches applicable to muslin and calico alone, it was calculated that employment was given in England and Scotland to 100,000 men and women, and at least 60,000 children.

The progress of the Irish in the same line of industry must not be overlooked, and the laudable and spirited exertions of captain Robert Brooke deserve to be more particularly noticed. In the year 1780, that gentleman established a cotton manufactory on his lands situated on the great canal about 18 miles W. of Dublin. In 1782, the government of Ireland, understanding that some of the manufacturers of Manchester intended to remove to America, and carry their machinery with them, found means to persuade them to go to Ireland, and gave captain Brooke about 3000 l. for settling them in houses upon his lands, and they afterwards advanced him 32,000 l. upon interest and security, that he might give employment to a great number of weavers who were then starving and riotous for want of employment in Dublin. By means of these and other acquisitions of inhabitants, the manufacturing village which was called Prosperous, consisted now of several hundred houses, erected on a spot where, in the year 1780, there stood one single hut; and the manufacture gave employment to about three thousand men, women, and children. Besides captain Brooke's, which was the principal one, there were at this time several other manufactures of cotton established in various parts of Ireland by the spirited exertions of individuals, and the liberal encouragement of parliament.

It may be proper here to observe, that two spinning mills were established in France, near Rouen, under the direction of Mr. Holker, an English manufacturer, who, with his partners, was assisted and patronized by the French government: and it was not long before Arkwright's machinery was even transported across the Atlantic, and a spinning mill erected in Philadelphia.

Calicoes were first brought hither from India in the year 1631, and derived their name from the province of Calicut, where they were chiefly made or exported. They were first manufactured in this country about the year 1772, or 1773. Various attempts had been made previous to this time to manufacture cloth with cotton warp or web, but owing to the imperfection of the twist or yarn, spun either on the one thread wheel or Jenny, they all proved unsuccessful. The warp was too flimsy, and unable to support the stretch or tension of the loom, or when it did, too soft to form a cloth of firm and useful texture. The improvements that rapidly followed the introduction of machine spinning, and more especially those of sir Richard Arkwright, soon remedied this defect; yet, though most excellent yarn or twist was produced, the manufacturers could not at first be prevailed upon to weave it into calicoes. Mr. Strutt, therefore, of Derby, in conjunction with Mr. Samuel Need, both in partnership with sir Richard Arkwright, attempted the manufacture of calicoes about the year 1773, and proved successful; yet after a large quantity had been made, it was discovered that they were subject to double the duty (*viz.* 6d. per yard) of cottons with linen warp, and when printed were prohibited. They had therefore no other resource than to ask relief of the legislature, which after great expence and opposition, they at length obtained, and thus laid the foundation of a branch of manufacture which has since become one of the most important in the kingdom.

The manufacture of calicoes was begun at Blackburn, in Lancashire, about this period also, at first from twist spun in the neighbourhood upon Jennies, but afterwards principally

from the water twist. The goods manufactured here before the introduction of calicoes, were *Blackburn greys*, made of cotton wool, but linen warp of Hamburgh or Irish yarn, but chiefly of the latter. These goods, which were the calicoes of that day, were manufactured as early as the year 1727, at which period all the cotton goods, such as pillows, jeans, jennets, most of the cords and thicksets were made with linen warp, and even the warps for dimities were half linen. The Blackburn greys were sold in the unbleached state to the calico-printers of London, and afterwards to those of Lancashire and Cheshire, till the introduction of the real calico put a stop to this manufacture about the year 1775.

Blackburn has since become the great mart for calicoes, and the chief source from whence the printers of Lancashire, as well as those of London and Scotland, are supplied.

The quantity manufactured, or rather sold there, (for the Blackburn houses employ weavers in all parts of the surrounding country, and even at considerable distances) amounted a year or two ago to upwards of one million pieces annually. The quantity now made is perhaps less than this, but of finer quality, a larger capital is employed, and the manufacture is on the increase.

The quantity of calicoes manufactured in the whole kingdom, not twenty years ago, was little more than half what the Blackburn market now affords, and it is probable that this forms but a small part of the quantity annually made in this country. They are chiefly printed into garments, shawls, and furnitures, both for home consumption, and a considerable foreign trade. The finer sorts are worn as dresses, white or plain, and large quantities are used for linings, and other purposes for which the coarser kinds of linen were formerly employed.

The lightness, as well as cheapness, of the calicoe, has rendered it a chief article of dress amongst all classes of people, and annihilated the manufacture of many of the lighter kinds of woollen and worsted stuffs, formerly so much in demand. The trade of Halifax, and the surrounding country, which consisted almost wholly in such stuffs, has gone entirely to decay, and been replaced by the manufacture of calicoes and other cotton goods: and such are the quantities now manufactured, more especially in the country around Colne, and thence to Bradford, that from 16 to 20,000 pieces are brought weekly to the Manchester market; the produce of those districts which adjoin, or are included between these two towns.

To the same improvements in spinning which gave birth to the manufacture of calicoes, we are indebted for that of muslin, a branch not less important to the country than honourable to our pride and industry as manufacturers. For this elegant article of dress all Europe had long been tributary to India, where the manufacture has, through the long lapse of ages, arrived at the greatest perfection. Muslins were first introduced into this country by the East India company, about the year 1670, before which time cambrics and Silesia lawns were worn, and such fine linens from Flanders and Germany, as were brought back in exchange for our woollen manufactures of various kinds exported thither in considerable quantities. The manufacture was attempted at Paisley as early as the year 1700. A few looms were employed, but this trade was soon annihilated by the introduction of the goods of India. Eighty years afterwards a more successful rivalry commenced. British muslins were first successfully introduced in the year 1781, but were carried to no great extent till 1785, since which period their progress has been rapid beyond all example. In the year 1787, it was computed, that not less than

500,000 pieces of muslin, including shawls and handkerchiefs, were annually made in Great Britain. The manufacture has, from that time to the present, continued progressively to increase and improve, and bids fair to become the most lucrative and extensive of any in this country. The rapidity with which it approaches to perfection, and its surprising extent in the short space of twenty years, are amongst the many important consequences that have resulted from the improvements in the art of spinning.

By the cheapness and superior quality of our yarn, we are enabled to employ thousands of looms in the production of this elegant and useful article of dress, to keep in this country millions of specie which was heretofore sent to the East to purchase this commodity, and to clothe ourselves with this fabric at one-third of the expence formerly required.

The demand for, and the use of this article, are proportionate to its cheapness and elegance, and it is not difficult to see that it will become a staple manufacture of this country.

Glasgow and Paisley in Scotland, and Bolton in Lancashire, are the chief seats of this manufacture, which is however considerably extended over many other parts of the country. India still maintains her superiority in the finer kinds of muslin, some of which of most exquisite beauty and fineness are sold in this country, as high as ten or twelve guineas *per* yard. In productions like these, no rivalry can exist; in India they are looked on as master pieces of art, and the time employed by an Indian weaver in their production would ruin an European.

The common kinds, or such as are more adapted to general use, are also preferred by our English ladies to those of home manufacture, on the score of their enduring greater hardships and retaining their colour, or rather whiteness, better. This excellence, which exists to a certain degree, is the result of no superiority in the manufacturing processes, but in the raw material, of which that of India is the finest and best in the world.

Muslins were manufactured at Zurich and St. Gall in Switzerland long before we succeeded, yet such were the advantages which the improvements in spinning afforded us, that till within these few years (during which the unsettled state of the continent has interrupted, and in some countries annihilated, all commercial intercourse) we supplied all Europe with muslins, not only of Indian, but British manufacture.

Nankeens and ginghams were manufactures, which, without the improvements of the spinner, could not possibly have succeeded.

These articles, like the two preceding, were formerly brought from the East exclusively. Rustians, dimities, jeans, quiltings, velvets, velverets, velveteens, and a variety of cotton goods, which the limits of our article will not allow us to particularize, have been improved to such a pitch, that Manchester has supplied all Europe with these fabrics.

Cotton hosiery forms no inconsiderable part of this immense manufacture, and it was the demand for cotton thread for the stocking weavers, that urged forward the improvements of Mr. Arkwright, and held out such strong inducements to those whose assistance first enabled him to give his invention to the world.

Exclusive of these various manufactures, great quantities of twist were exported to the continent, and a considerable part of the yarn spun in Manchester, before the late disastrous occurrences in Germany, was employed in the foreign loom. It was this demand for twist, which our continental rivals were unable to produce of equal quality

or price with ours, which raised this branch of the cotton manufacture to a state of prosperity, of which some idea may be formed, when it is stated that the various establishments for spinning only in this country, when in full activity, give employment to near 180,000 persons, a number little short of that which is employed in France in all the different branches of the cotton manufacture together, and which, according to the report of Chaptal, late minister of the Interior, amounts to near 200,000.

The value of these improvements in spinning was so obvious and so important, that it is not surprising they were soon diffused over the continent, notwithstanding every precaution used to prevent it. By the emigration of mechanics, and the clandestine exportation of machinery constructed here, our neighbours soon became possessed of our improvements, and had we paused in our exertions, the superiority we had acquired would long ere this have passed away. France, as we have just observed, has a great population employed in the manufacture of cotton. Prussia and Germany have many and increasing establishments, and in the two former countries, and in the hereditary dominions of the emperor of Germany, our piece goods have been long prohibited.

Our spinners however, by their ingenuity, and the improvement and perfection of their machines, have still kept the lead; and the attention of our manufacturers is now directed to the perfection of those operations more immediately connected with the labours of the loom, in which, till within these few years, little has been done. Every day brings forth new discoveries, and it is not difficult to see that what has already been achieved, and what, from the general spirit of improvement which is now abroad, must inevitably follow, will soon place us far beyond the reach of competition in the manufacture of cotton goods, and give us advantages greater than ever we enjoyed since its first establishment in this country. Before we enter into such a detail of these improvements however, as will enable our readers fully to comprehend their nature and extent, it will be proper to take a short view of the different operations and processes through which the thread passes in its progress from the hands of the spinner to the loom.

The thread is of two kinds, viz. *twist*, so called from its being harder twisted than the other, forming a stouter thread, and used for the web or warp of piece goods, and *weft*, which is a looser, softer thread, and used for the woof. The *weft* is delivered to the weaver in small oblong rolls called *cops*; in the state they are stripped off the spindles of the mule or Jenney. When these are used, a small pointed piece of wood or skewer is carefully passed through the axis of the cop into the place formerly occupied by the spindle, and one end of it being held between the teeth, the thread is wound off the cop upon the weaver's bobbin by a wheel somewhat smaller in size, but the same in principle as the common one thread wheel on which all the spinning was formerly performed.

This is generally done by children, and the bobbins are then ready for the shuttle. Twist undergoes several operations before it is ready for the loom. It is delivered by the spinner either in *hank*, or *cop*.

Hank twist is that which is spun on the water frame, from the bobbins of which it is *reeled* into hanks of a determinate length, each measuring 840 yards. The value and fineness of the thread are proportionate to the number of hanks in a pound, and they are denominated by numbers, as Nos. 20, 50, 100, &c. which express the hanks which a pound of twist contains. In this state it is generally *sized*,

an operation which is intended to give additional strength and tenacity to the thread, and enable it to support the different operations in its passage to the loom. It consists in impregnating the thread fully with thin size, chiefly formed of wheat flour boiled in water, with the addition of a little glue. The twist is carefully worked in this and afterwards wrung and dried. The thread acquires considerable strength by this operation, and the loose fibres are all firmly attached or glued to its surface. It is then delivered to the winder.

Winding is that operation by which the thread is transferred to the warping bobbin, either from the cop, hank, or twist frame bobbin.

Formerly this was chiefly done by females, and the work was carried home and performed by any of the family not engaged in domestic concerns, on a small wheel that turned two bobbins at a time.

This mode is still in use, but the work has been greatly abridged and facilitated by the use of machines of various constructions, for a description of which, see MACHINE.

Cop twist is that which is spun on the mule or Jenney. It is reeled only occasionally to ascertain its value and fineness, and is delivered in cops to the winder.

The next operation is that of *warping*, or the formation of the web. The machine on which this is performed is an octagonal prism five or six feet high, and somewhat less in diameter, revolving vertically, and put in motion by a band and pulley placed under the seat of the warper. The bobbins which furnish the thread are suspended horizontally in a frame on one side. Twenty-eight or thirty threads, forming together a system called a *half beer*, are wound round the prism in a spiral form from top to bottom. The machine is then turned the contrary way, and the thread wound round the prism upwards from bottom to top, and this is repeated backwards and forwards till a sufficient number of *half beers* have been wound to form a web of the breadth required.

When finished, and the ends properly secured, the whole is wound off and coiled upon the hand into a round ball called the *warp*. For further particulars of this operation, and a description of the machine, see MILL.

If the thread has been previously sized in the hank, it is now ready for the loom, but if the warp is made of cop twist, that operation is next performed.

The warps are boiled several hours in water till they are thoroughly penetrated and softened; after draining some time they are then uncoiled and worked in the size till fully impregnated, after which the superfluous size is squeezed out, and they are suspended on poles to dry: the warp is then ready for the loom.

Without this operation of sizing, which, as we have before observed, gives strength and tenacity to the thread, it would not support the friction of the loom. Two threads are passed between each dent of the reed, and at each stroke of the treadle one ascends whilst the other descends. There is therefore a constant friction of the threads upon each other, as well as against the teeth of the reed. The motion of the reed itself also backwards and forwards, and of the healds up and down, is very severe upon the warp, and unless it has been well penetrated by the size, and its fibres well cemented or glued together, this continual rubbing is sufficient to destroy its texture.

Good sizing prevents this, but it is still further aided by another operation called *dressing*, which is performed by the weaver himself after the warp is got into the loom. This consists first in applying with a brush a kind of paste made

of wheat flour well boiled, to which is often added a small portion of common salt; sometimes of potash, and sometimes even a little tallow.

It is in fact a repetition of the operation of sizing, with this difference, that the dressing is applied chiefly to the surface of the thread, which is slightly smeared with the paste, and brushed uniformly in one direction from the healds to the beam, by which means the loose fibres are all disposed evenly one way, and firmly glued fast to the thread.

In summer the warp is dried simply by fanning it, but in winter, and in damp cold weather, a hot iron is lightly passed over it. It is then dressed again with a brush dipped in tallow or butter, with which it is slightly greased. This gives suppleness and smoothness to the thread, and greatly diminishes the friction of the healds and reed. As such a portion of the warp as is extended between the healds and beam can alone be dressed at one time, this is woven, and the dressing repeated again upon another portion, and so on alternately dressing and weaving till the whole of the web is finished.

Various improvements on these different processes have taken place during the last six or eight years, which have made greater or less progress in proportion to their importance. We shall enumerate, therefore, not only those of recent date, but such as, though known some time, have not been generally adopted.

The weaver's bobbin is still wound by hand in the manner already described, though the use of a small machine, by which twenty bobbins or upwards are wound at once, is daily gaining ground. They are to be seen now in almost every weaver's cottage where several looms are employed. This labour is further abridged by a very ingenious contrivance for which a patent has been obtained. The cops, instead of being wound, are compressed or squeezed till they are small enough to enter the shuttle. The winding here is done away, and the cops thus compressed are preferred, by the weavers to the common bobbin. In those large establishments where the different processes, such as spinning and weaving, are carried on together, the cops are spun small enough to enter the shuttle without compression. The weft is transferred at once from the spindle of the mule to the weaver's shuttle, and the time and waste of winding, and even of compressing, saved entirely.

On the same principle also, a considerable reduction has been made in the labour of reeling and winding twist. Till within a late period, the practice has uniformly been to reel it into hanks from the bobbin it was spun on, to size it in the hank, and then wind it for warping. An obvious reduction of this labour is to warp it directly from the bobbin it is spun on, and size it in the warp like cop twist. For reasons, however, which it will not be necessary here to enter into, this has been found impracticable. It is, however, transferred to the warping bobbin without the intermediate labour and waste of reeling, and the sizing is done in the warp.

Considerable improvements in the mode of sizing have been made within these few years, especially in the sizing of warps.

Formerly, the practice was to work the warp in the warm size by the hand, the heat of which was of course limited to that degree which could be readily borne by the workman. Experience having proved that the hotter the size, the more evenly and perfectly was the warp penetrated, various contrivances were adopted for applying it at a high temperature. Amongst others are oblong troughs furnished with several pairs of rollers, through which the warp passes, and is strongly compressed whilst immersed in the hot size.

Mr. Marland's idea of placing the twist in an exhausted receiver, and admitting the hot size, promises considerable advantages in some cases, and when the plan has been matured, will no doubt be susceptible of many applications.

But the greatest improvement that has been made in these different processes, and one that must eventually effect a complete revolution in the whole system, is Messrs. Ratcliffe and Ross's mode of dressing. Hitherto this operation has been performed by the weaver in the manner we have already described, at the expense of one-third of his time and labour. As it is only possible for him to dress at once as much of the work as is contained between the healds and beam, he is scarcely got settled to his work, after each operation, before he is again called off to dress another portion. By this continual interruption of one species of labour by another totally different, it must be obvious to every one, that not only much time is lost, but that the labour itself cannot be equally well performed.

There is a delicacy and certainty of touch in weaving, dependant on long habit and experience, and on which the evenness and goodness of the cloth depends.

If the force with which the woof or weft is driven up by the reed, be not always alike, if it is greater at one time and less at another, the cloth will be thicker and thinner at those places, and such is the nicety on which this depends, that the most experienced weaver, after an interruption of some hours, cannot at once regain it.

Messrs. Ratcliffe and Ross dress the whole of the warp before it is wound upon the beam, the labour of the weaver is therefore uninterrupted, and his attention directed solely to one object. This alone is a great point gained, but it is attended also by other, not less important, advantages. Great part of the intellectual skill required in weaving is in the dressing and beaming of the warp; the mere mechanical part of throwing the shuttle, &c. is soon acquired, even by a boy. A more accurate division of labour, by reducing the beaming and dressing to a system by which they are better, more economically, and more expeditiously performed than before, has removed the great difficulty in the art of weaving, and rendered it in a great measure the employment of children.

From what we have already said, it will appear that the object in dressing and sizing is nearly the same, and Messrs. Ratcliffe and Ross, by this improved mode of dressing, have succeeded in reducing these operations to one. They have gone still further; they have done away the necessity of warping, by forming the web at once from the bobbin, and thus reduced the warping, sizing, dressing, and beaming, to one operation. A thousand bobbins and upwards supply the materials for the warp, which in its progress is properly disposed and arranged, sized, dressed, and finally wound upon the beam. This improvement, which may justly be regarded as the most important that has taken place in weaving since the invention of the fly shuttle fifty years ago, must in the end effect a complete change in the system of labour. Great however as its advantages are, some time must necessarily elapse before it can be accommodated to general use. In large establishments, where the different processes of the manufacture are carried on together, such as spinning, weaving, and the labour immediately connected with them, it has been adopted with the happiest success, but the weaving in this country is chiefly done in the cottages of the poor, and to their use the costly and bulky apparatus of Messrs. Ratcliffe and Ross is not adapted.

To derive all the advantages possible from this improvement, therefore, it will be necessary either that the weaving

be done in large shops, to each of which a dressing machine may be attached, or that the warps be delivered to the country weavers ready dressed and wound upon the beam. The former plan is daily gaining ground, and perhaps it is not difficult to foresee, that at no very distant period all the weaving of the country will share the fate of the spinning, and quit the cottage for those larger establishments in which it will be susceptible of better management, and more accurate division of labour.

The last improvement, which we shall notice in the manufacture of cotton, and which, when once established, will complete what Arkwright has so happily begun, is that of weaving by machinery. Various attempts have been made of late years to apply the great moving powers, steam, and water, to the common loom. Mr. Dolignon, many years ago, constructed a loom adapted, as we are told, to the manufacture of all kinds of cloth. It might be wrought by the power of wind, water, steam, or animal strength, and possessed an instinctive capacity (if we may be allowed the phrase) of knowing when any thread of the weft or warp was broken, in which case the loom ceased its motion, thus calling on the attendant to repair the damage, which being done, it immediately went on as before; six of these looms might be attended with ease by a girl of sixteen, or an aged or infirm person of either sex. The inventor did not live to reap the fruit of his labour, nor to introduce his machine properly to the world. He died soon after its completion, when he had brought it to a state of perfection satisfactory to himself, and with him perished the result of his industry and talent. Such is the account which the friends of Mr. Dolignon give of this invention: since that time several other looms of similar construction have been invented.

Mr. Austin of Glasgow has produced one, a model of which is deposited at the house of the Society of Arts in the Adelphi, in favour of which numerous testimonies were transmitted to the secretary. In the year 1798, a loom on this construction was set to work at Mr. Monteith's spinning works near Glasgow, which answered the purpose so well, that a building was erected by Mr. Monteith for containing thirty looms, and afterwards another to hold about 200.

The model deposited in the Adelphi is an improvement on those first made for Mr. Monteith, whose name we do not however see amongst the list of those who bear testimony to its value. A loom of this kind, says the inventor, occupies only the same space as a common loom. The expence is about one-half more. The reeling, winding, warping, beaming, looming, combing, dressing, fanning, greasing, drawing bores, shifting beddles, rods, and temples, which is nearly one half of the weaver's work, together with the general waste accompanying them; all which occur in the operation of the common loom, do not happen in this, which by its single motion, without trouble, performs every operation after the spinning, till the making of the cloth is accomplished. One weaver and a boy are sufficient to manage five looms of coarse work, and three or four of fine work. The construction of this loom is so complicated, that the society have not, in their Transactions, given the public a drawing of it, conceiving that a model only could render it intelligible.

Other looms of a more simple, and consequently of more useful construction, have been invented by Messrs. Horrocks and Marland of Stockport near Manchester, which, combined with the dressing machine of Messrs. Ratcliffe and Rosa, promise to be of considerable utility, and have already been tried on a sufficiently extensive scale by the inventors. The dressing machine, indeed, has removed the

great difficulties in machine weaving, and without it nothing important or advantageous could have been accomplished. It has also rendered the machine loom itself of less importance, by simplifying the art of weaving so much as to render that the employment of boys, which was formerly entrusted only to experienced weavers. To the rapid extension of this improvement, however, there are objections at the present moment arising from moral as well as political considerations which must greatly retard its progress, and we must look to happier times for the proof of its general utility, and its final adoption or rejection.

The preceding sketch, short and imperfect as it is, will serve to convey some idea of this immense and important manufacture. Of the population at present engaged in it, and of its annual value, we have only such conjectures to offer as are founded on those materials which are within the reach of individuals, and unless government order such an enquiry, it can only be estimated by the importation of cotton, which is for the most part manufactured at home.

Perhaps the manufacture of Scotland, as being in a narrow field, is more within the reach of observation than that of England; we therefore venture to lay before our readers, as being apparently an approximation to the truth, the following,

Estimate of the state of the cotton manufacture in Scotland, made up in the year 1796 at Glasgow, the centre of the principal commerce and manufactures of that kingdom.

39 water mills, which cost for machinery and buildings 10,000 l. each	-	-	£ 390,000
and work	124,800 spindles		
1200 Jennies 84 sp. each	100,800 at 6l. each		7,200
600 mules 144 sp. each	86,400 at 30l. each		18,000

Total, working by } 312,000 spindles.
day and night

Building for the Jennies cost - 75,000

Capital vested in machinery and buildings £ 490,200

The yarn annually spun is valued at £ 1,256,412
The cotton 4,629,043 lbs, average value 2s. 462,904

The people employed are estimated at 25,000 of both sexes, young and old, but the greater part under 15 years of age, whose labour, aided by machinery, thus improves the value of the raw material in the first stage of manufacture.

From which deduct wages estimated at 793,508
500,000

Remains for cost, and wear and tear of machinery, and proprietors profits, the sum of 293,508

The annual value of calicoes and muslins, now deservedly esteemed the staple of Scotland, when finished, including the excise duty on a part of them which are printed, and the cost of tambouring and needle work on about a third part of them, was then estimated at £ 3,108,549

Value of the cotton yarn as } £ 1,256,412
above -

Yarn got from England. 520,000

£ 1,776,412

The wages of weavers, tambourers, needle-workers, the charges, the profits of the manufacturers, and the revenue paid to government, thus amounted to

£1,332,137

Which great sum is produced by capital, ingenuity, management, and labour in the subsequent stages of the business.

The cotton manufacture in Scotland	}	38,815 weavers.
employs - - -		
For winding warp and weft	}	12,938 women.
And supposing $\frac{1}{4}$ of the muslin adorned with needle work		
- - -		
and girls most children.	}	105,000 women.
Besides those employed in the spinning branch		
- - -	}	25,000
- - -		
Hence it appears that	- - -	181,753 persons

derive their immediate subsistence from the cotton manufacture in Scotland, and also a proportional number in England, employed in producing yarn to the value of 520,000 £; besides the innumerable people of all classes concerned in providing necessaries and accommodations of every kind for that great multitude, and in constructing and repairing the machinery and buildings; and the cultivators of the cotton in the East and West Indies, seamen, merchants, &c. who are all wholly or partly supported by this most beneficial manufacture, by which the cotton is raised, taking the whole manufacture together, to about seven times the value it was of when imported.

The cotton manufacture has increased very much in Scotland since the year 1796. The imports of cotton into the kingdom in the year 1800, were nearly treble those of the year 1796. The printing business however appears to have declined a little, as may be inferred from the following

Account of the Calicoes, Muslins, Linens, and Stuffs, printed in Scotland in the years 1796 and 1800.

		1796			1800.		
		Rate of Duty	Yards.	Amount of Duty.	Yards.	Amount of Duty.	
		d.		£ s. d.		£ s. d.	
Foreign Calicoes and Muslins	- -	7	141,403	4,124 5 1	78,868	2,300 6 4	
British Calicoes and Muslins	- -	3 $\frac{1}{2}$	4,258,567	62,103 19 1 $\frac{1}{2}$	4,176,939	60,913 13 10 $\frac{1}{2}$	
Linens and Stuffs	- -	3 $\frac{1}{2}$	1,185,500	17,288 10 10	1,220,714	17,802 1 7	

In England and Wales, on the contrary, the printing business has increased during the above period, as will appear from the following

Account of the Calicoes, Muslins, Linens, and Stuffs, printed in England and Wales in the years 1796 and 1800.

		1796.			1800.		
		Rate of Duty.	Yards.	Amount of Duty.	Yards.	Amount of Duty.	
		d.		£ s. d.		£ s. d.	
Foreign Calicoes and Muslins	- -	7	1,750,270	51,049 10 10	1,577,536	46,011 9 4	
British Calicoes and Muslins	- -	3 $\frac{1}{2}$	24,363,240	355,297 5 0	28,692,790	418,436 10 5	
Linens and Stuffs	- -	3 $\frac{1}{2}$	3,464,862	50,529 4 11	3,232,073	47,134 7 11	

If we follow the calculation assumed in an estimate laid before a committee of the house of commons, that the duty is one tenth of the value, we may estimate the value of the British calicoes and muslins printed in England and Wales in 1796, at

£ 3,552,972 0

And those in 1800 at

4,184,365 0

From these statements, which are official, it appears that in 1800 there were printed about a million and a half of calicoes and muslins in Great Britain, exclusive of linens, stuffs, and foreign calicoes. From that time, to the year 1806, the business has continued progressively to increase, the amount of duties on printed goods for that year being

upwards of 600,000 £, which will bring the number of pieces printed nearly to two millions.

The quantity of white calicoes and muslins made in England and Wales, is certainly much greater than that of the printed; probably not less than three million pieces annually.

From the signatures to the petition of the journeymen calico-printers to the house of commons in the year 1806, it would appear that, in Great Britain and Ireland, the number is 7000; we suspect however that this number includes apprentices, and that the list also has been swelled, as is usual in such cases, by unfair means.

During the progress of the work we shall have frequent opportunities of reverting again to the subject of the cotton manufacture, and of supplying those omissions which, in a business of such magnitude and extent, when submitted to individual investigation, must unavoidably occur. We shall conclude therefore with observing that, from the best in-

formation we have been able to collect, and from calculations founded on the quantity of the raw material imported into the country and of goods exported, it appears that the cotton manufacture of these realms gives employment to 800,000 persons, and that its annual value is upwards of 30 millions.

COTTON MANUFACTURE.

PLATE I.

CALICO PRINTING.

Fig. 1.

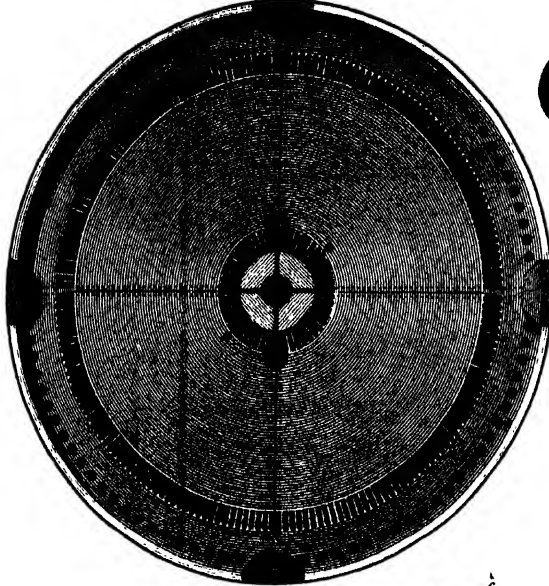


Fig. 2.

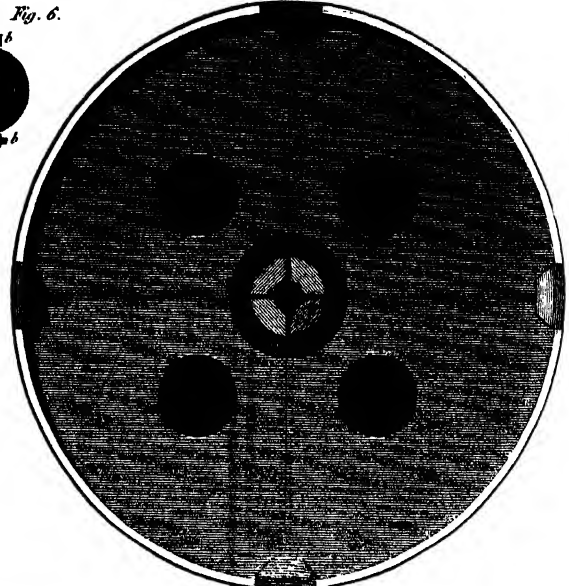


Fig. 5.

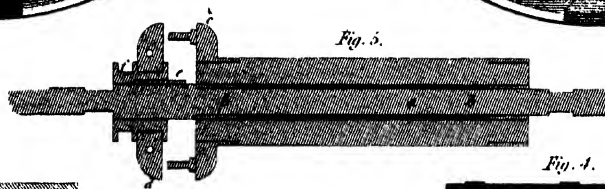
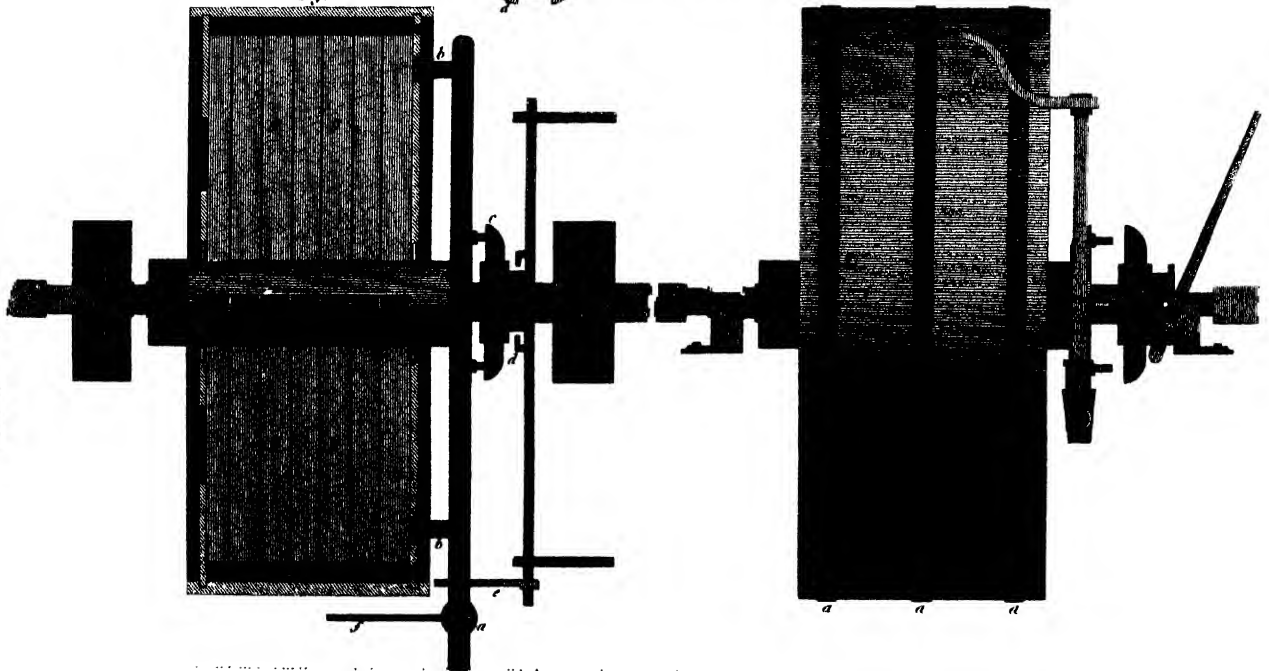


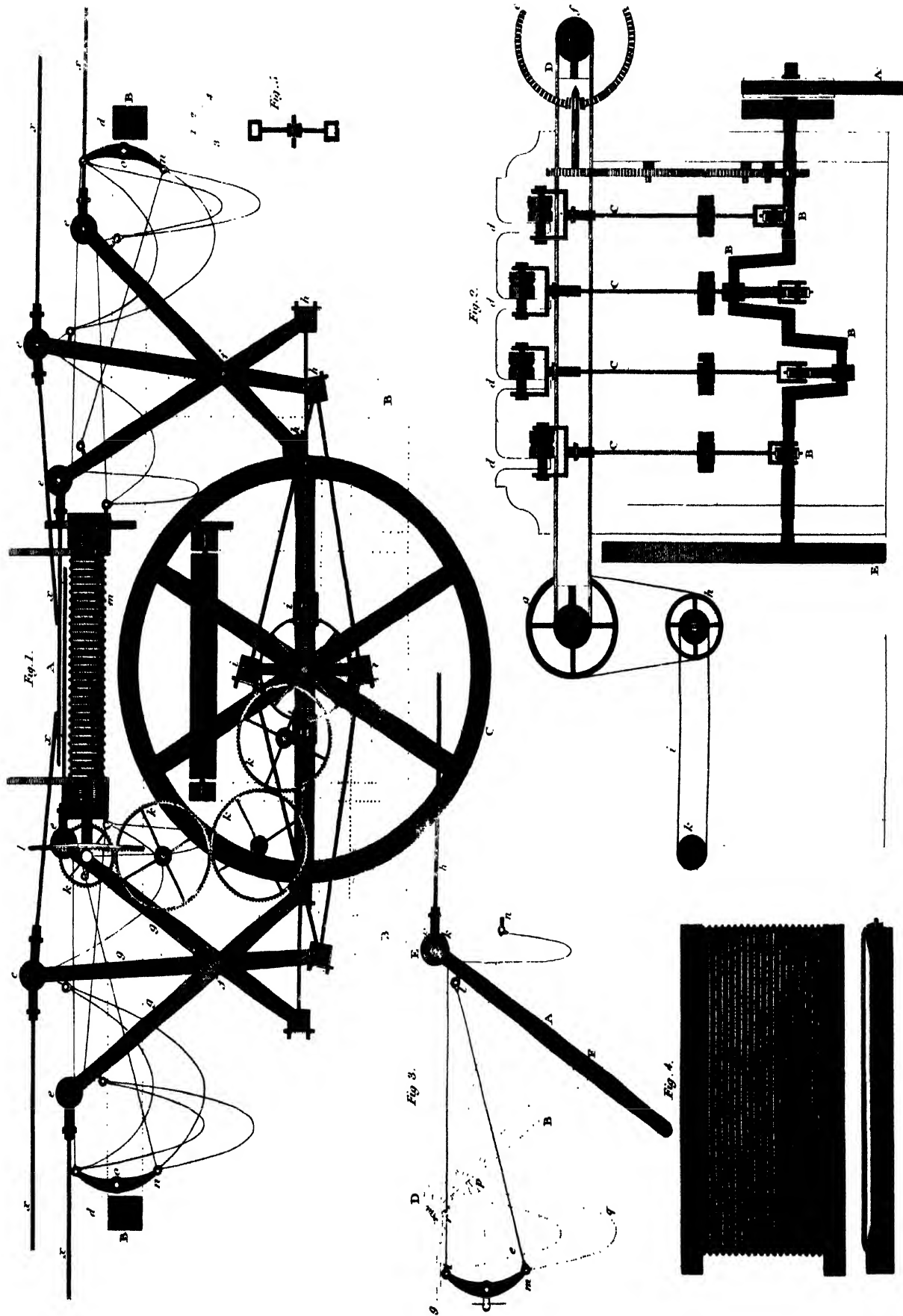
Fig. 3.

Fig. 4.



COTTON MANUFACTURE. BATTING MACHINE.

PLATE.



Plan.

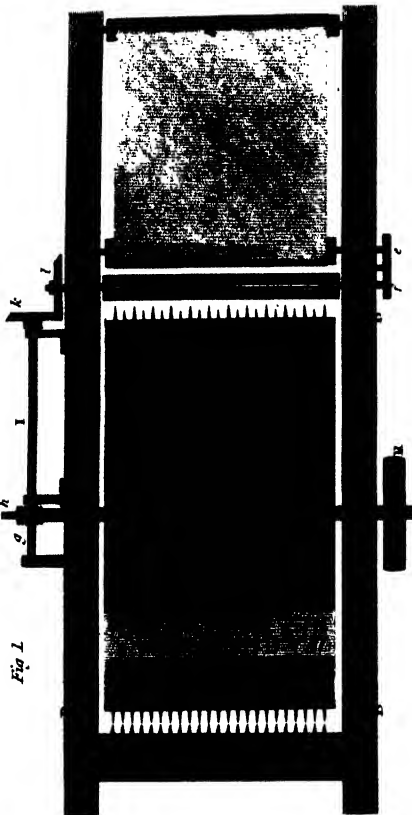


Fig. 5.

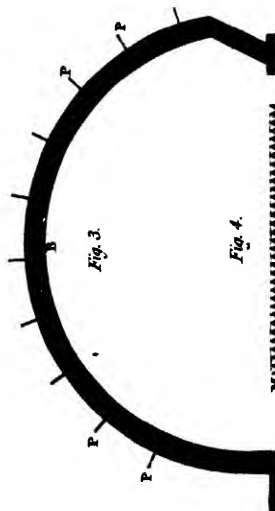


Fig. 2. Section.

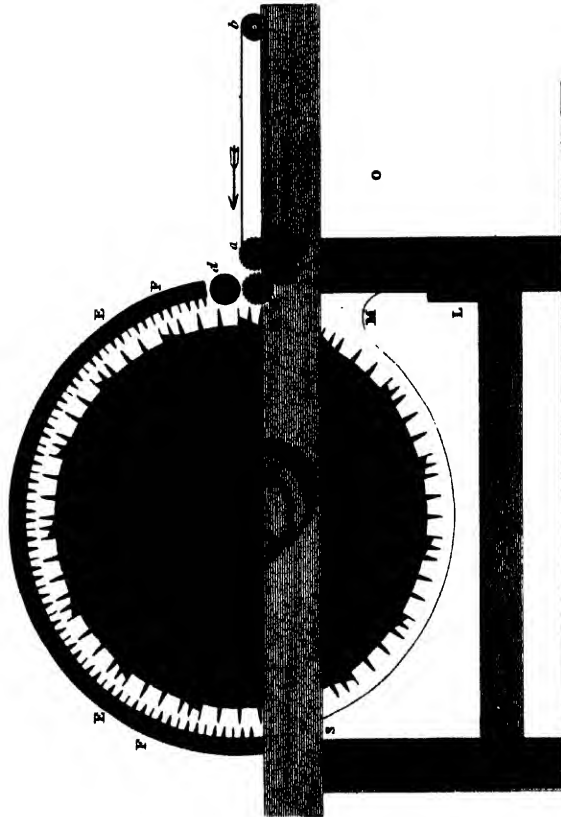
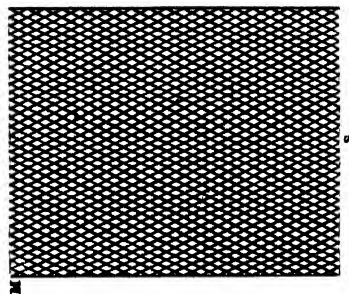


Fig. 4.



COTTON MANUFACTURE.

PLATE IV.

CARDING.

Fig 1. Plan

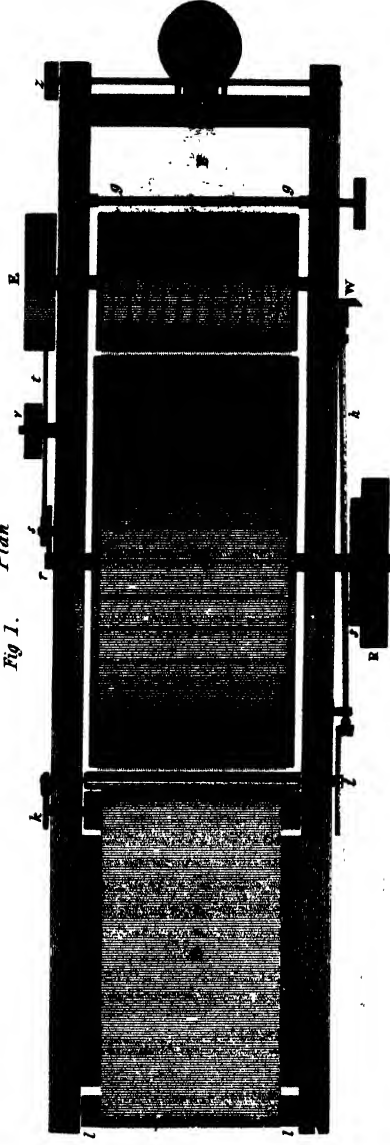


Fig 2. Section

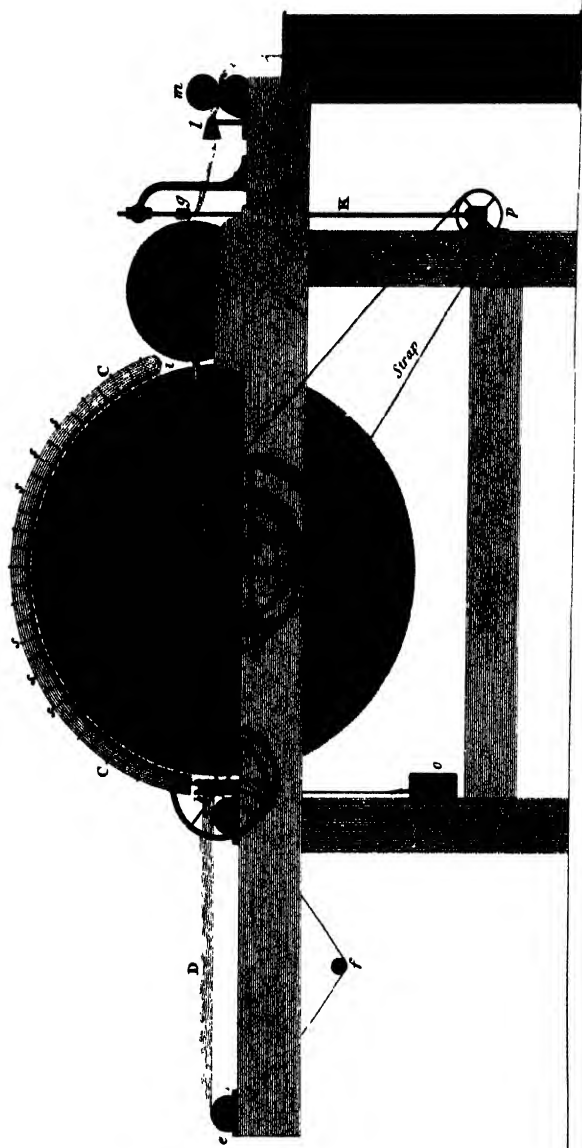


Fig 4.

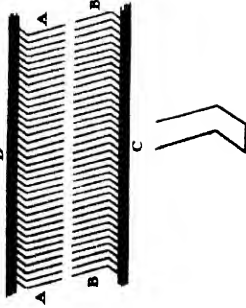
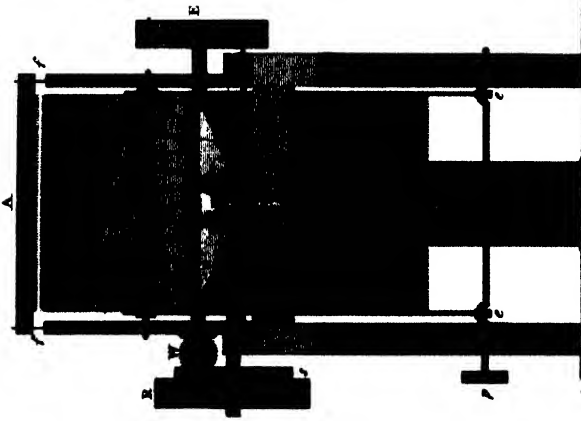
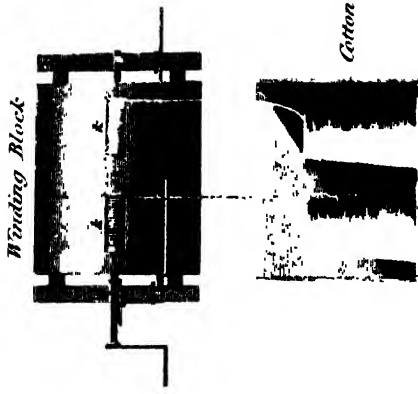
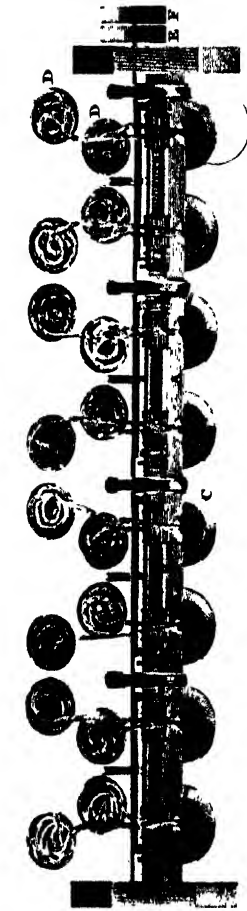


Fig 3.

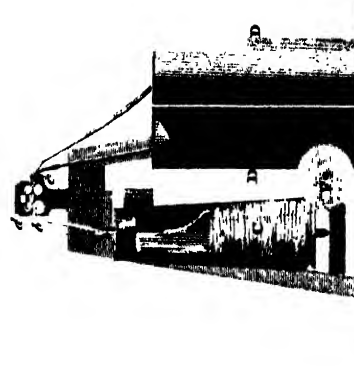
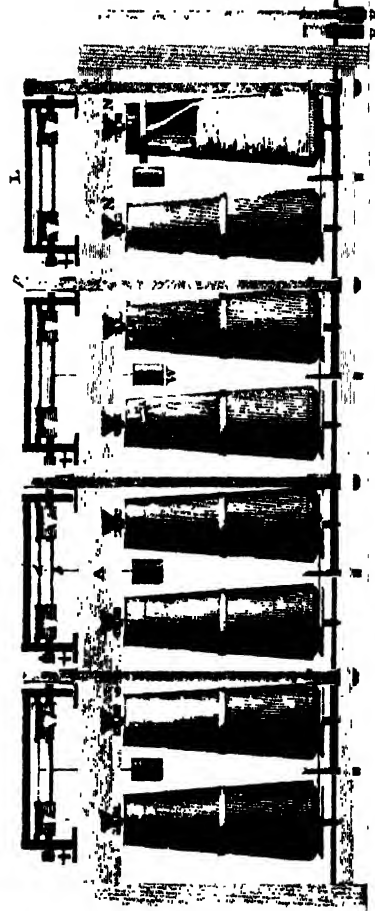


COTTON MANUFACTURE OF CAN FRAME.

PLATE



- A Roller beam.
- b Front Roller.
- c Back Roller.
- d Top front Roller.
- e Revolving Can.
- f Roller weights.
- g Can Pulley.
- DD Back Cams.
- E Driving Pulley.
- F Loose Pulley.
- NN Can Funnel.
- L Cover.
- p Front roller Pulley.
- k & Bobbins.

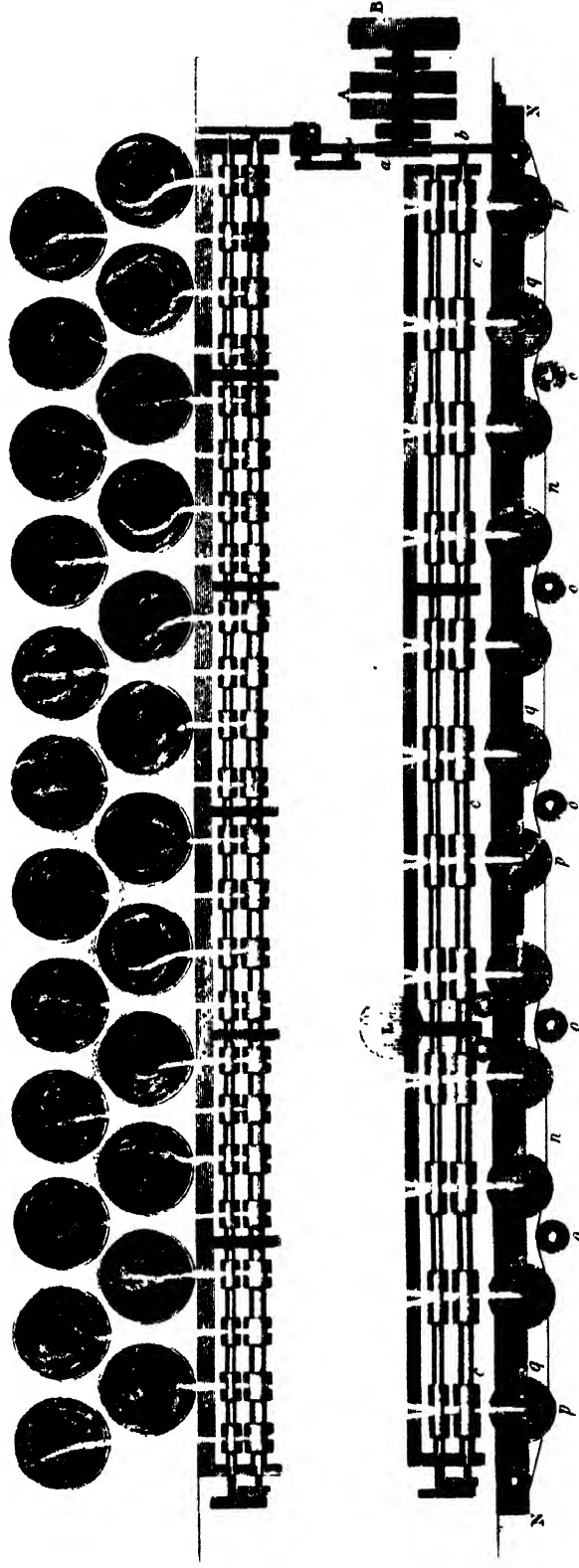


COTTON MANUFACTURE.

PLATE VII.

ROVING FRAME, Plate Ist.

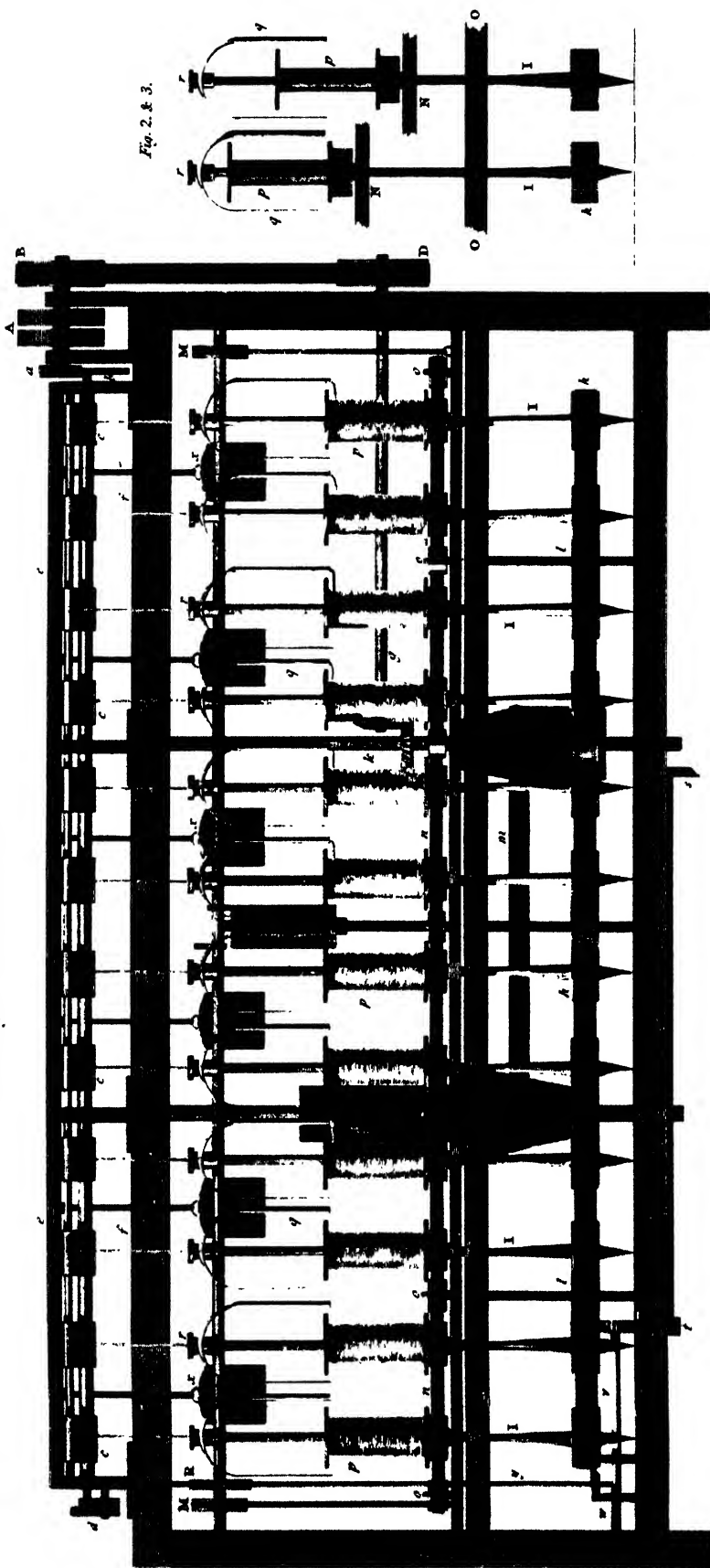
These cans contain the slivers brought from the Drawing frame.



Horizontal Plan of the Machine called Double Speeder.

COTTON MANUFACTURE. ROVING FRAME termed *DOUBLE SPEEDER*.

A 100 ft. SCALE FOR THE FIG. 2 & 3.



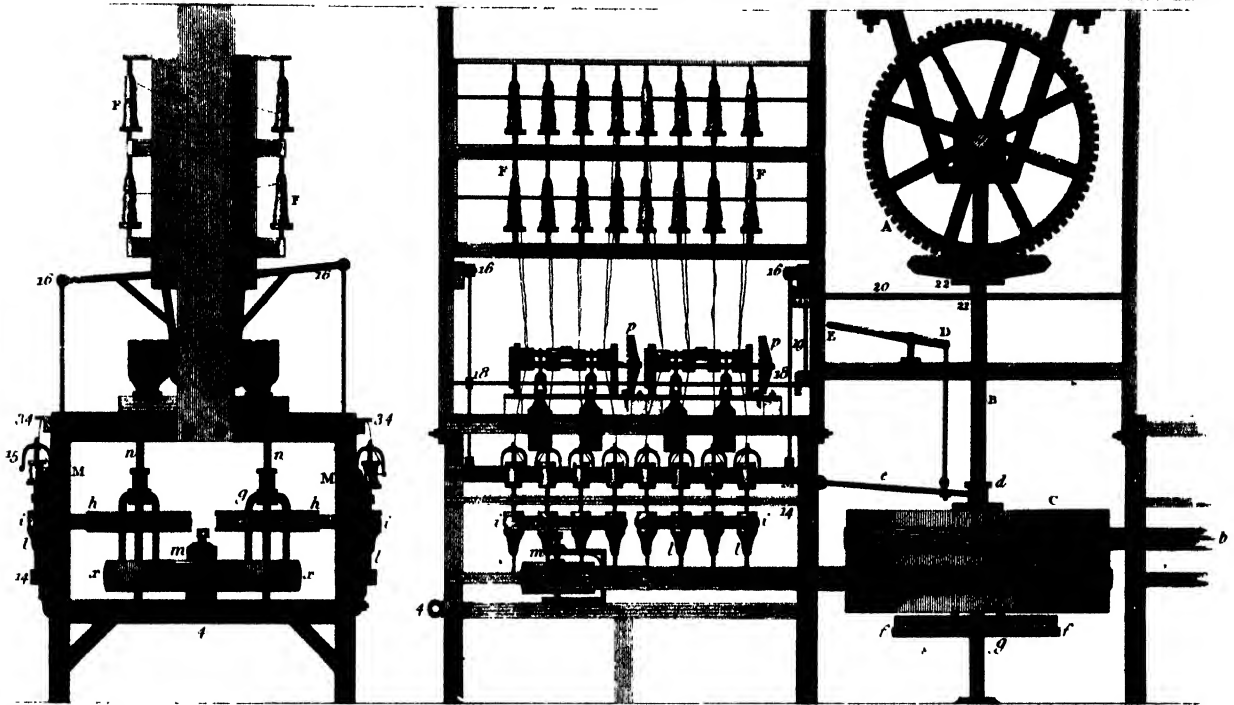
COTTON MANUFACTURE.

WATER SPINNING FRAME.

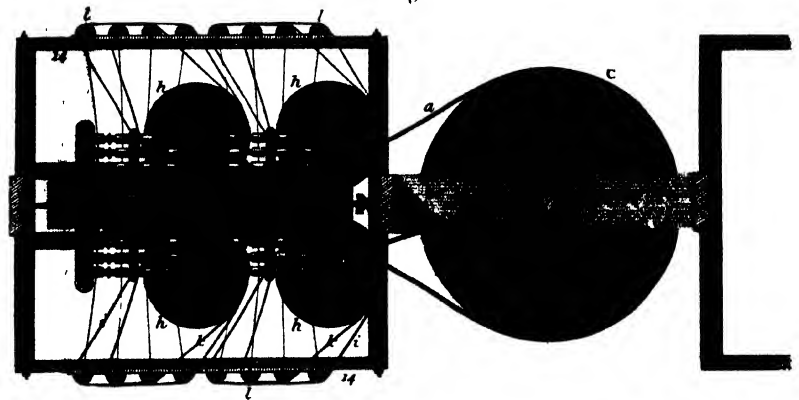
End View. Fig. 2.

Elevation. Fig. 1.

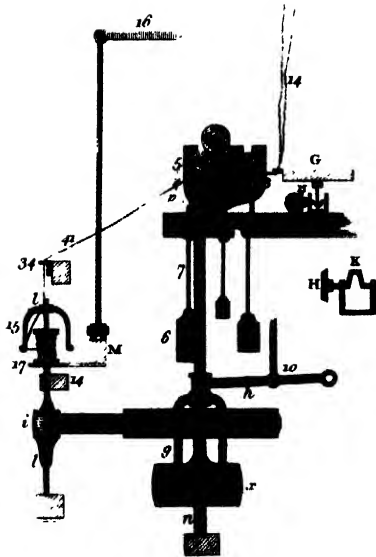
Plate IX.



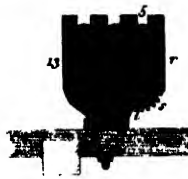
Plan. Fig. 3.



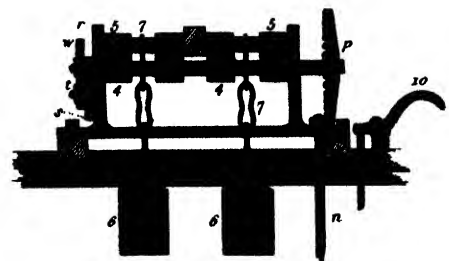
Spindle enlarged. Fig. 4.



End View. Fig. 6.



Elevation of Rollers. Fig. 5.



OTTON MANUFACTURE.
THROSTLE SPINNING FRAME.

PLATE X.

Fig. 1.

Fig.

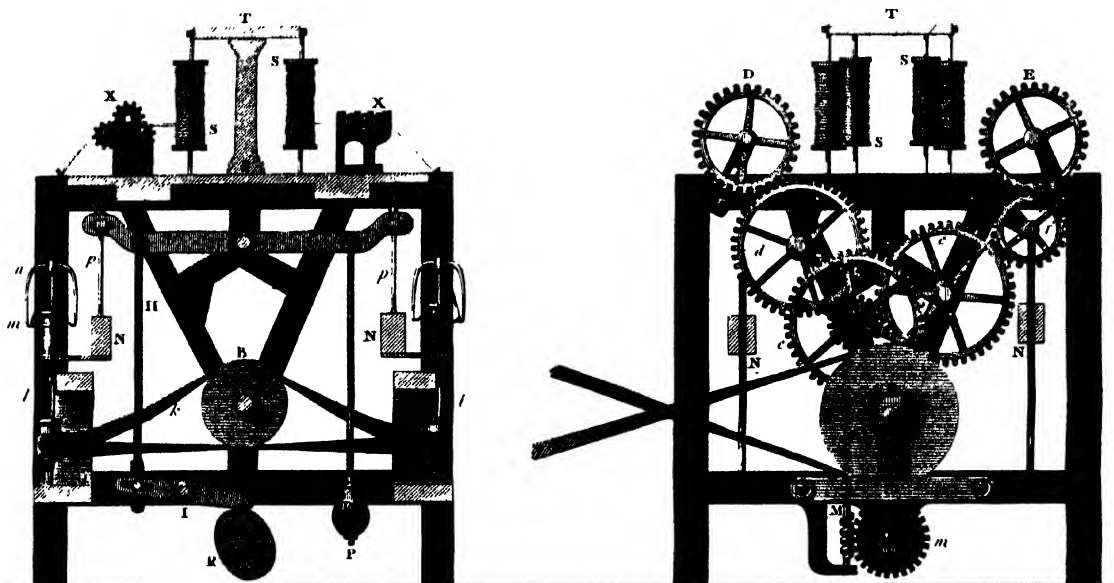


Fig. 3.

Elevation in Front.

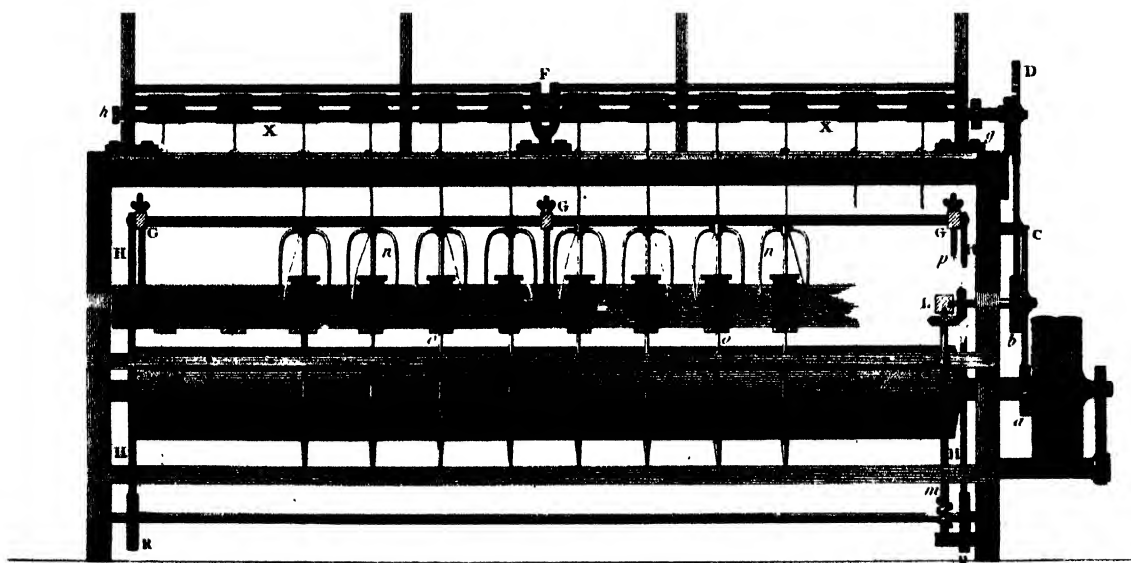


PLATE XI.



Fig 3.

Elevation in Front.



COTTON MANUFACTURE.
REELING.

PLATE XII.

Fig. 1.

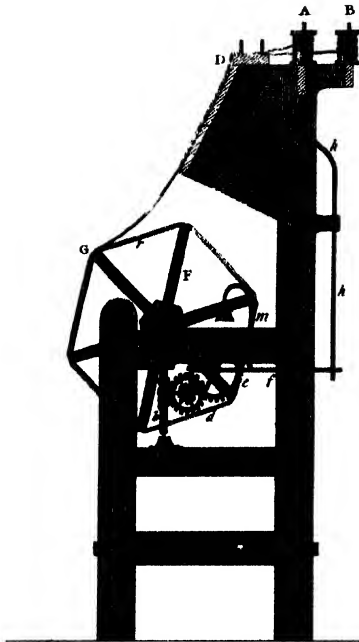
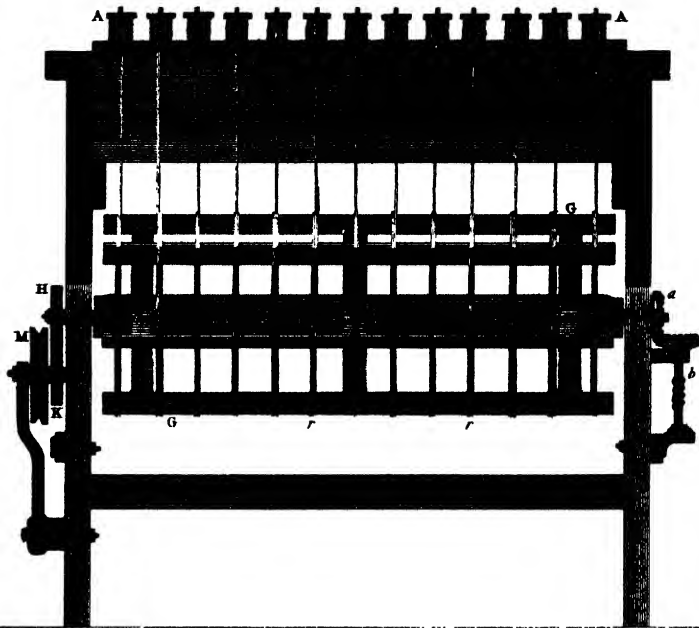


Fig. 2.

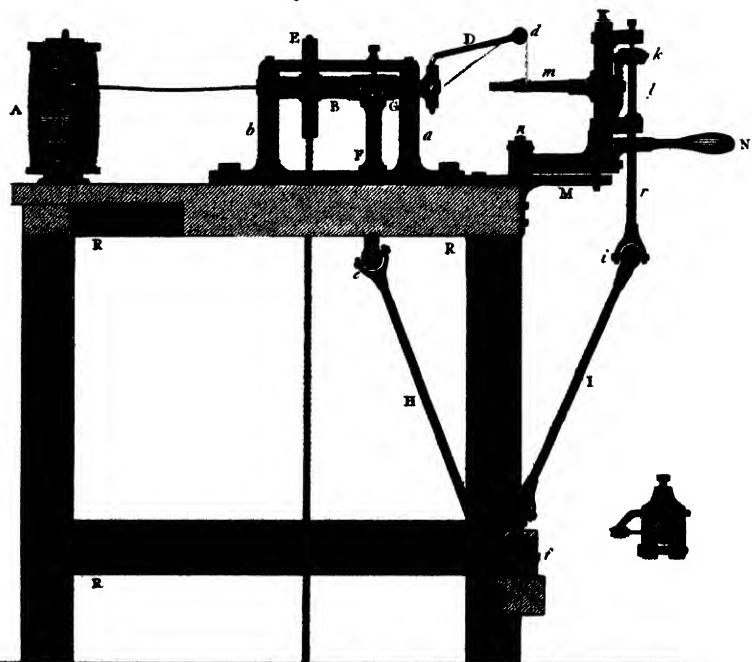


Machine for winding sewing cotton into Balls.

Fig. 3.



Fig. 6.



COTTON MANUFACTURE.

PLATE XIII

Fig. 2.

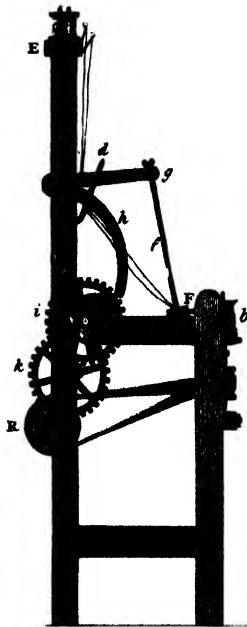
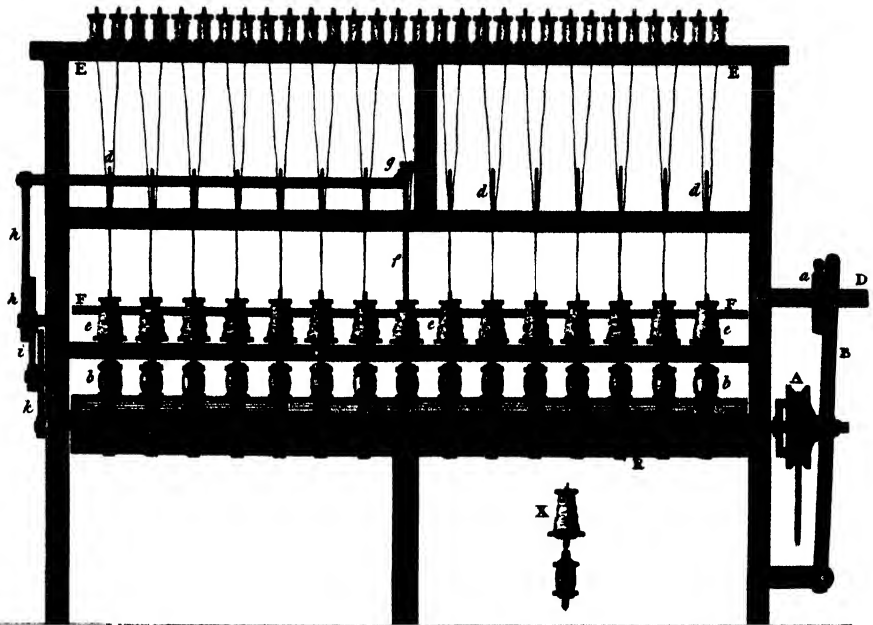
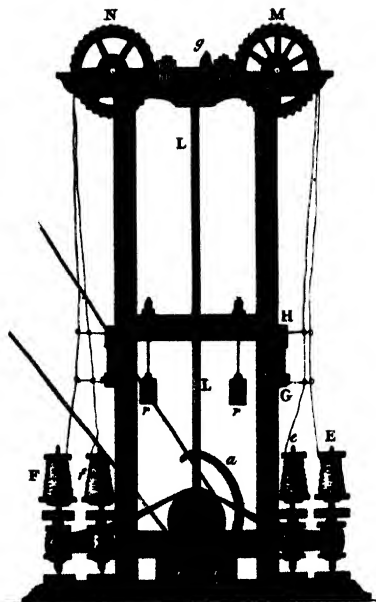


Fig. 1. DOUBLING MACHINE.

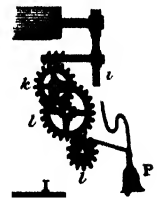
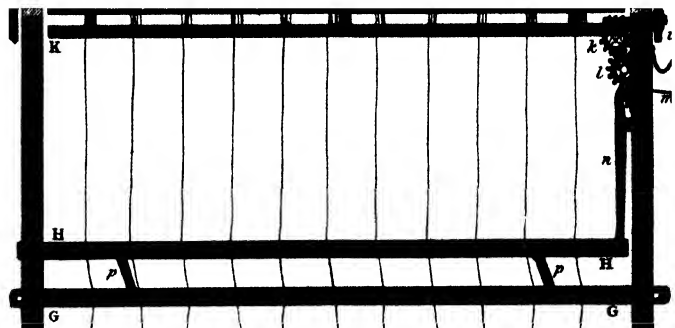


TWISTING MACHINE.

End View. Fig. 3.



Elevation. Fig. 4

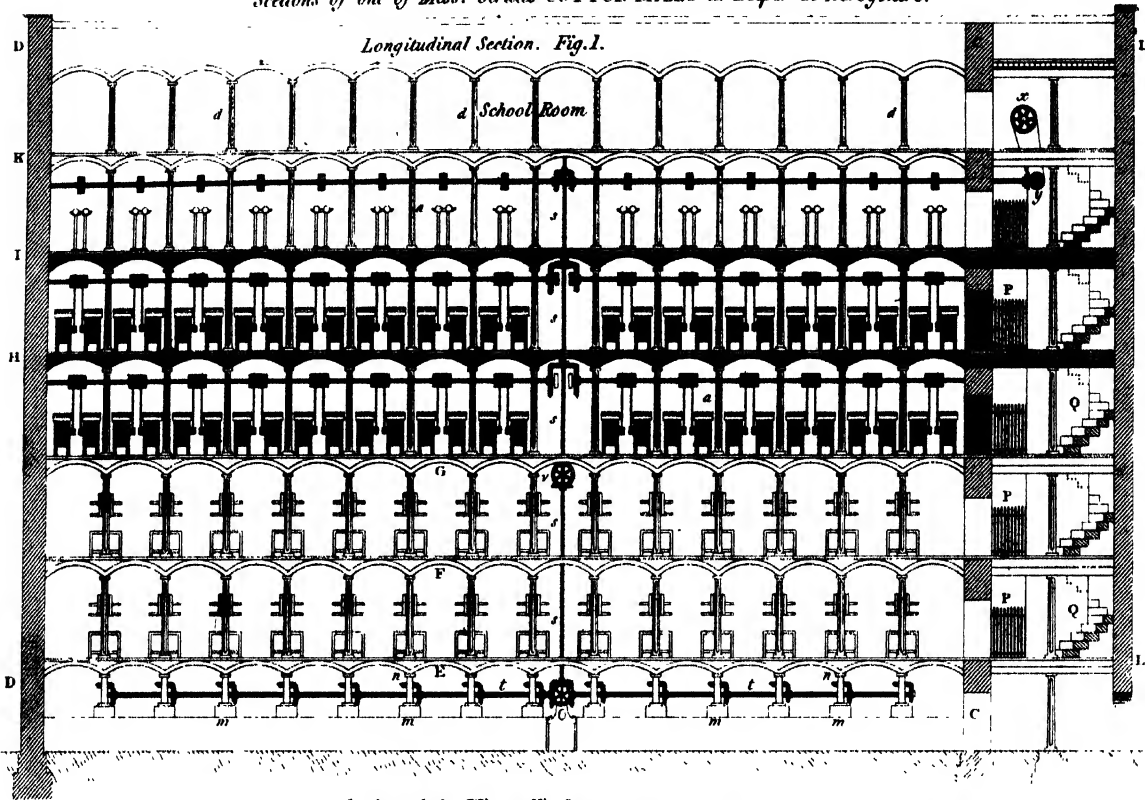


COTTON MANUFACTURE.

PLATE XIV.

Sections of one of Messrs Strutt's COTTON MILLS at Belper in Derbyshire.

Longitudinal Section. Fig. 1.



Section of the Wing. Fig. 3.

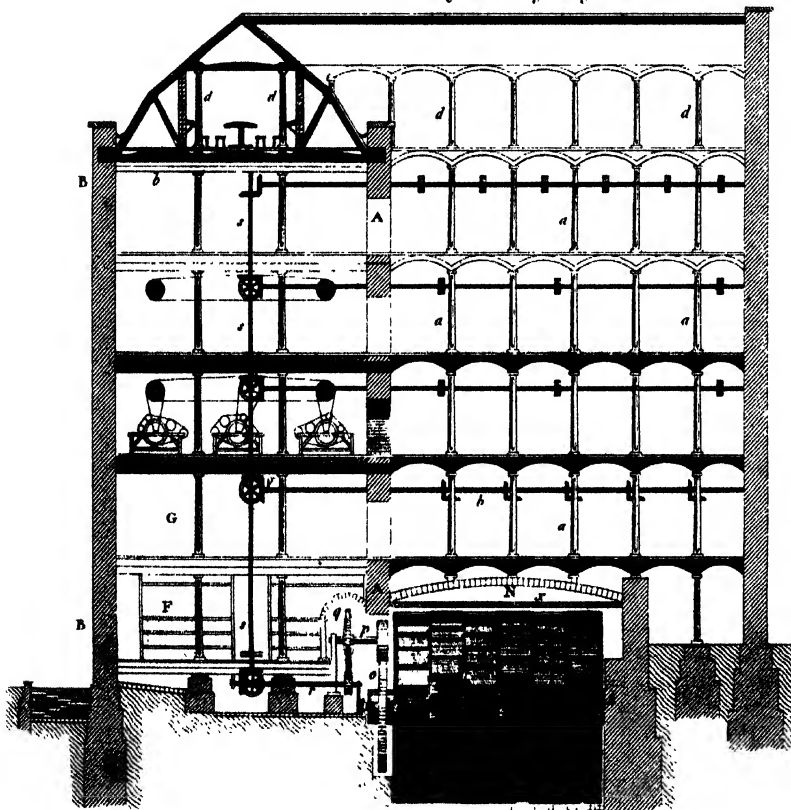
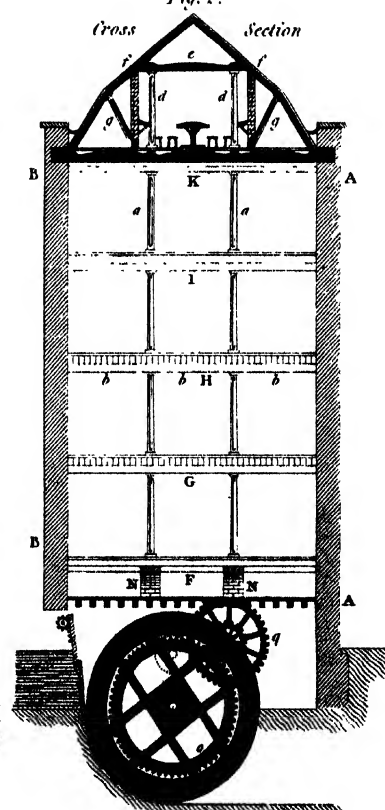


Fig. 2.

Gross Section



Crane

CRANE, in *Hydraulics*, a popular name for a *Siphon*; which see.

CRANE, in *Mechanics*, a machine used in *Building* and in *Commerce*, for raising large stones, and other weights, to certain heights, or lowering them to certain depths.

M. Perrault, in his notes on Vitruvius, makes the crane the same with the *corvus*, or raven, of the ancients.

The modern crane consists of several members, or pieces, the principal being a strong perpendicular beam, or arbor, firmly fixed in the ground, and sustained by eight arms, coming from the extremities of four pieces of wood laid across, through the middle of which the foot of the beam passes. About the middle of the arbor the arms meet, and are mortised into it: its top ends in an iron pivot, on which is borne a transverse piece, advancing out to a good distance in manner of a crane's neck; whence its name. The middle and extremity of this are again sustained by arms from the middle of the arbor: and over it comes a rope, or cable, to one end of which the weight is fixed; the other is wound round the spindle of a wheel, which turned, draws the rope, and that heaves up the weight; to be afterwards applied to any side or quarter, by the mobility of the transverse piece on the pivot.

There are several improvements of this useful machine mentioned in Desaguliers's *Experim. Philos.* p. 178, *seq.* particularly how to prevent the inconveniences arising from sudden jerks, as well as to increase its force by using a double axis in *peritrochio*, and two handles.

The crane is of two kinds; in the first kind, called the *rat-tailed crane*, the whole machine, with the load, turns upon a strong axis; in the second kind, the gibbet alone moves on its axis. We shall refer to Desaguliers, *ubi supra*, for a particular account of different cranes, and recite improvements in the construction of them: beginning with a description of one, in which most of them are combined, invented by the late Mr. Padmore of Bristol. This consists of wheels, axles, pulleys, ropes, and a gib or gibbet. *Plate XVIII. Mechanics, fig. 2.* When the rope, H, is hooked to the weight K, a man turns the winch A, on the axis of which is the trundle B, which turns the wheel C, on whose axis, D, is the trundle E, which turns the wheel F, with its upright axis G, on which the great rope, HH, winds as the wheel turns; and going over a pulley, I, at the end of the arm, d, of the gib *ccde*, it draws up the heavy bur-

den K; which, being raised to a proper height, as from a ship to the quay, is then brought over the quay by pulling the wheel, Z, round by the handles z, z, which turns the gib by means of the half wheel, b, fixed on the gib-post *cc*, and the strong pinion, a, fixed on the axis of the wheel Z. This wheel gives the man that turns it an absolute command over the gib, so as to prevent it from taking any unlucky swing, such as often happens when it is only guided by a rope tied to its arm d; and people are frequently hurt, sometimes killed, by such accidents.

The great rope goes between two upright rollers i and k, which turn upon gudgeons in the fixed beams f and g; and as the gib is turned towards either side, the rope bends upon the roller next that side. Were it not for these rollers, the gib would be quite unmanageable; for the moment it were turned ever so little towards any side, the weight, K, would begin to descend, because the rope would be shortened between the pulley I, and axis G; and so the gib would be pulled violently to that side, and either be broke to pieces, or break every thing that came in its way. These rollers must be placed so, that the sides of them, round which the rope bends, may keep the middle of the bended part directly even with the centre of the hole in which the upper gudgeon of the gib turns in the beam f. The truer these rollers are placed, the easier the gib is managed, and the less apt to swing either way by the force of the weight K.

A ratchet-wheel, Q, is fixed upon the axis D, near the trundle E; and into this wheel falls the catch or click R. This hinders the machine from running back by the weight of the burden K, if the man who raises it should happen to be careless, and so leave off working at the winch, A, sooner than he ought to do.

When the burden, K, is raised to its proper height from the ship, and brought over the quay by turning the gib about, it is let down gently upon the quay, or into a cart standing thereon, in the following manner. A man takes hold of the rope *tt*, (which goes over the pulley v, and is tied to a hook at S, in the catch R,) and so disengages the catch from the ratchet-wheel Q; and then, the man at the winch, A, turns it backward, and lets down the weight K. But if the weight pulls too hard against this man, another lays hold of the handle V, and by pulling it downward, draws the gripe, U, close to the wheel Y, which, by rubbing hard against the gripe, hinders the too quick descent of the weight; and not only so, but even stops it at any time,

if required. By this means, heavy goods may be either raised or let down at pleasure, without any danger of hurting the men who work the engine.

When part of the goods is craned up, and the rope is to be let down for more, the catch, R, is first disengaged from the ratchet-wheel Q, by pulling the cord *t*; then the handle, *q*, is turned half round backward, which, by the crank, *nn*, in the piece *a*, pulls down the frame, *b*, between the guides *m* and *m*, (in which it slides in a groove,) and so disengages the trundle, B, from the wheel C: and then, the heavy hook, *β*, at the end of the rope, H, descends by its own weight, and turns back the great wheel, F, with its trundle, E, and the wheel C; and this last wheel acts like a fly against the wheel, F, and hook *β*; and so hinders it from going down too quick; whilst the weight, X, keeps up the gripe, U, from rubbing against the wheel Y, by means of a cord going from the weight, over the pulley, *w*, to the hook, W, in the gripe; so that the gripe never touches the wheel, unless it be pulled down by the handle V.

When the crane is to be set at work again, for drawing up another burden, the handle, *q*, is turned half round forwards; which, by the crank *nn*, raises up the frame *b*, and causes the trundle, B, to lay hold of the wheel C; and then, by turning the winch A, the burden of goods, K, is drawn up as before.

The crank, *nn*, turns pretty stiff in the mortise near *o*, and stops against the farther end of it when it has got just a little beyond the perpendicular; so that it can never come back of itself: and therefore, the trundle, B, can never come away from the wheel C, until the handle, *q*, be turned half round backward.

The great rope runs upon rollers in the lever L M, which keep it from bending between the axle at G and the pulley I. This lever turns upon the axis, N, by means of the weight O, which is just sufficient to keep its end, L, up to the rope; so that, as the great axle turns, and the rope coils round it, the lever rises with the rope, and prevents the coils from going over one another.

The power of this crane may be estimated thus: suppose the trundle, B, to have 13 staves or rounds, and the wheel, C, to have 78 spur cogs; the trundle, E, to have 14 staves, and the wheel, F, 56 cogs. Then, by multiplying the staves of the trundles, 13 and 14, into one another, their product will be 182; and by multiplying the cogs of the wheels, 78 and 56, into one another, their product will be 4368, and dividing 4368 by 182, the quotient will be 24; which shews that the winch, A, makes 24 turns for one turn of the wheel, F, and its axle, G, on which the great rope or chain, H I H, winds. So that, if the length or radius of the winch, A, were only equal to half the diameter of the great axle G, added to half the thickness of the rope H, the power of the crane would be as 24 to 1: but the radius of the winch being double the above length, it doubles the said power, and so makes it as 48 to 1: in which case, a man may raise 48 times as much weight by this engine as he could do by his natural strength without it, making proper allowance for the friction of the working parts. Two men may work at once, by having another winch on the opposite end of the axis of the trundle under B; and this would make the power double.

If this power be thought greater than what may be generally wanted, the wheels may be made with fewer cogs in proportion to the staves in the trundles; and so the power may be of any degree that is judged to be requisite. But if the weight be so great as will require yet more power to raise it (suppose a double quantity), then the rope, H, may be put under a moveable pulley, as *β*, and the end of it tied to

a hook in the gib at *t*; which will give a double power to the machine, and so raise a double weight hooked to the block of the moveable pulley.

When only small burdens are to be raised, this may be quickly done by men pushing the axle, G, round by the handspikes *y, y, y, y*; having first disengaged the trundle, B, from the wheel C. and then, this wheel will only act as a fly upon the wheel F; and the catch, R, will prevent its running back, if the men should inadvertently leave off pushing before the burden be unhooked from *β*.

Lastly, when very heavy burdens are to be raised, which might endanger the breaking of the cogs in the wheel F: their force against these cogs may be much abated by men pushing round the handspikes *y, y, y, y*, whilst the man at A turns the winch. Ferguson's Lectures on Select Subjects, 4to. p. 52, &c.

If the axis, G G, be placed horizontally, and instead of the wheel, F, a larger wheel be fixed to it, which may be turned by men walking in it, we shall have another kind of crane; the rope will coil round the axle as the wheel turns, and the gib-work is the same as in the other sort of crane. Mr. Padmore contrived to prevent the danger attending the use of this construction, by putting cogs all round the outside of the wheel, and applying a trundle to turn it; by which addition the power is increased in the proportion of the number of cogs to the number of staves in the trundle: and in order to hinder its running back by the force of the weight, should the men within it slip, or leave off walking, he added a ratchet-wheel to the axis of the trundle, like that already described. Two winches may also be fixed to the ends of the axle, by working which the men in the wheel would be much assisted. On the axle of the trundle he likewise fixed a gripe-wheel, such as has been already described, by means of which heavy burdens may be let down without the least danger.

Mr. Ferguson has contrived and described a new and safe crane, with four different powers adapted to different weights; for which he received a reward of 50*l.* from the Society for the encouragement of arts, &c. In this crane (see *Plate XVIII. Mechanics, fig. 3.*) A represents the great wheel, and B its axle, on which the rope, C, winds. This rope goes over a pulley, D, in the end of the arm of the gib E, and draws up the weight F, as the winch, G, is turned round. H is the largest trundle, I the next, and K is the axis of the smallest trundle, which is supposed to be hid from view by the upright supporter L. A trundle, M, is turned by the great wheel, and on the axis of this trundle is fixed the ratchet-wheel N, into the teeth of which the catch, O, falls. P is the lever, from which goes a rope, Q Q, over a pulley, R, to the catch; one end of the rope being fixed to the lever, and the other end to the catch. S is an elastic bar of wood, one end of which is screwed to the floor: and, from the other end goes a rope (out of sight in the figure) to the farther end of the lever, beyond the pin or axis on which it turns in the upright supporter T. The use of this bar is to keep up the lever from rubbing against the edge of the wheel U, and to let the catch keep in the teeth of the ratchet-wheel: but a weight hung to the farther end of the lever, would do full as well as the elastic bar and rope.

When the lever is pulled down, it lifts the catch out of the ratchet-wheel, by means of the rope Q Q, and gives the weight, F, liberty to descend: but if the lever, P, be pulled a little farther down than what is sufficient to lift the catch, O, out of the ratchet-wheel N, it will rub against the edge of the wheel, U, and thereby hinder the too quick descent of the weight; and will quite stop the weight, if pulled hard. And if the man who pulls the lever should happen inad-

vertently to let it go; the elastic bar will suddenly pull it up, and the catch will fall down and stop the machine.

W, W, are two upright rollers, above the axis or upper gudgeon of the gib E: their use is to let the rope, C, bend upon them, as the gib is turned to either side, in order to bring the weight over the place where it is intended to be let down: which rollers ought to be so placed, that if the rope, C, be stretched close by their outmost sides, the half thickness of the rope may be perpendicularly over the centre of the upper gudgeon of the gib; for then the length of the rope between the pulley in the gib and the axle of the great wheel, will be always the same, in all positions of the gib, and the gib will remain in any position to which it is turned.

The powers of this machine may be easily calculated: the horizontal-wheel has ninety-six cogs, the largest trundle twenty-four staves, the next largest has twelve, and the smallest has six. So that the largest trundle makes four revolutions for one revolution of the wheel; the next makes eight; and the smallest makes sixteen. When a winch is occasionally put upon the axis of either of these trundles for turning it, the handle of the winch describes a circle in every revolution equal to twice the circumference of the axle of the wheel; and therefore the length of the winch doubles the power gained by each trundle. So that if the winch be applied to the axle of the largest trundle and turned four times round, the wheel and axle will be turned once round, and the power will move through eight times as much space as the weight rises through: in which case the power will be to the weight as eight to one; *i. e.* a man may raise (allowing for friction) eight times as much weight by the crane, as he might by his natural strength without it. If the second trundle be used, the proportion of the power to the weight will be as sixteen to one; and with the smallest trundle, as thirty-two to one. The power may again be doubled by drawing up the weight by one of the parts of a double rope, going under a pulley in the moveable block, which is hooked to the weight below the arm of the gib; for then the power will be as sixty-four to one: and by increasing the number of pulleys, the power will be proportionably increased. See Supplement to Ferguson's Lectures, p. 3, &c. or Phil. Transf. vol. liv. art. 3. p. 24.

An improved crane for wharfs has lately been invented by Mr. Robert Hall of Basford, near Nottingham, who was rewarded with 40 guineas by the Society of Arts. The invention chiefly consists in expanding a set of bars parallel to the axis of a crane, by means of which the velocity of the ropes in raising weights may be diminished or increased, in proportion to the load which is to be raised. An engraving and description of this crane may be seen in the 12th volume of the Transactions of the Society, p. 283, &c. We have already observed under the article CAPSTAN, that the capstan with a compound barrel, consisting of two cylinders of different radii, may be converted into a crane or windlass for raising weights. Such a crane is evidently superior to those in common use, with the additional advantage of allowing the weight to stop in any part of its progress, without the aid of a ratchet-wheel and catch, as the two parts of the rope pull on contrary sides of the barrel. The rope, indeed, which coils round the larger part of the barrel, acts with a longer lever, and consequently with greater force than the other; but as this excess of force is not sufficient to overcome the friction of the gudgeons, the weight remains stationary in any part of its path. A crane of this kind was erected, in 1797, at Bordenton in New Jersey, by Mr. M'Kean, for the purpose of raising logs of wood to the frame of a saw-mill, 10 feet distant from the ground.

We are happy here to lay before the public a design for a crane, by the late Mr. John Smeaton, through the liberality of Sir Joseph Banks, who kindly permitted our draughtsman to make a reduced copy of the original drawing, which he purchased, with many others, since the demise of Mr. Smeaton. The machine was erected at the wool quay custom-house, London, in 1789. *Fig. 2, (Plate XIX. Mechanics)* is a plan of it; *fig. 3*, an elevation; and *fig. 1*, a section of the barrel: the same letters of reference are used in each figure. A is the barrel upon which the chain is wound; it has seven turns of a spiral groove cut upon it, to receive the lower half of the links of the chain, as will be clearly understood from *fig. 3*; *a, a, fig. 2*, are two of four handles (the others not being shewn) screwed to the end of the barrel by long bolts going through its whole length, as shewn in *fig. 1*; the other ends of the same bolts attach to the barrel, a wheel, B, with hooked teeth. The barrel, with its wheel, B, and handles, has a metal bush driven into its centre, and well fitted to a nicely turned arbor, *b*, in the section, *fig. 1*, so as to turn upon it freely without shake. This arbor has a shoulder, C, upon it truly turned, against which the great wheel, D, fits, and is held fast to it by four screws (*fig. 2.*); the great wheel, D, and barrel are connected together by means of two clicks, *d, d, (fig. 3.)* turning on pins made fast to the wheel, and pressed by springs into the teeth of the ratchet-wheel B. The great wheel, D, has 96 teeth, and is turned by a lantern, E, of 11 staves, on the arbor *f*. F is a fly-wheel fitted on the same arbor by a shoulder, in the same manner as the great wheel. G is a broad wooden wheel on the arbor, *f*, encompassed half round by a brake, *g*, formed of four pieces; it is brought to touch the wheel by a foot lever, H, *fig. 3*, and a weight at the opposite end of the lever lifts it off the wheel when not in use. I is a ratchet-wheel, and *i* the click to prevent the crane running back; K, K, are the winches by which it is turned. The ratchet and click on the barrel are used when the crane is lowering goods, and the chain is to be drawn up with any work; the workmen then turn the barrel by the four handspikes, *a, a*, the sloping sides of the ratchet-wheel lifting up the clicks, *d, d*, and passing by, without the labour and loss of time of turning the wheels; and likewise, when the crane is used for raising goods, and the chain is to be let down without any load, the barrel must be turned back a small space, and the clicks disengaged, by pushing one of their tails, *n* or *n*, for which purpose they are connected to move together by a small rod *o*; the barrel then runs down by the weight of the chain, and if that is not sufficient, the workman assists it by the handspikes, *a, a*. The contrivance of the grooved barrel is of very great use, as without it the chain lies in such a manner that the action of the load tends to twist open the links laterally. Mr. Gilbert Gilpin of Shifnal was rewarded by the Society of Arts, in 1803, for the same invention, without perhaps knowing Mr. Smeaton had applied it before him. As he has very well explained the advantages of this construction, we shall make use of his own words from the Transactions of the Society, vol. ii. p. 3.

Every chain formed of oval links has a twist in itself, arising from a depression given by the hammer to each link in the welding: the twist may be seen by holding the piece of the chain by one end, and viewing the links edgewise as it hangs down; and this circumstance, so trifling in appearance, is not so in its effects; and it has in consequence a perpetual tendency (even when reefed perfectly straight in pulleys, and on the barrels of cranes) to assume a spiral form, which a plain cylindrical barrel, and the common pulleys with semi-circular grooves, are not in the least calculated to prevent. Hence the alternate links of the chain, in coiling round a

barrel, or working over pulleys, form obtuse angles in assuming the spiral form, bearing upon the lower parts of their circumferences, and forming as it were two levers, which wrench open and crush each other in proportion to the weight suspended, as well as prevent the freedom of motion in the links themselves, and thereby load the chain with additional friction.

A still greater obstruction to the uniformity of its motion, is the tendency which the chain has to make a double coil, as it approaches the middle of the barrel, and crosses its centre, and that of the pulleys at right angles, by means of which the chain is frequently broken by the sudden jerk, caused by the upper coil slipping off the undermost.

It is to these causes that all the accidents that occur to workmen and machinery, from the failure of chains, may be attributed, (bad iron excepted,) and which form the sole objection to their becoming a general substitute for ropes.

As a preventive to these evils, says this writer, I have grooves cast in iron pulleys, of sufficient dimensions to receive the lower circumferences of the links of the chain, which work vertically: those which work horizontally and form the gudgeon part of the chain (if we may be allowed the expression,) bearing up on each side of the grooves.

The barrels are also of cast iron, with spiral grooves of the same dimensions, at such distance from each other as to admit the chain to bed without the danger of a double coil; by these means the links are retained at right angles with each other, the only position for free and uniform motion.

The links of the chains are made as short as possible, for the purpose of increasing their flexibility, and they are reefed perfectly free from twist in the pulleys and on the barrels, for the same reason.

When applied in block, the grooves in the pulleys prevent the different falls of the chain from coming in contact, and render plates between them (as in the common way)

totally unnecessary; the pulleys are in consequence brought closer together, the angle of the fall from block to block considerably diminished, and the friction against the plates entirely avoided. Brass guards, with grooves opposite to those in the pulleys, are rivetted to the blocks, to prevent the chain getting out of its birth from any accidental circumstance. This method of working chains I first put in practice for Messrs. T. W. and B. Botfield, at their works, in July 1803; and it is applied in the working of cranes capable of purchasing from ten to fifteen tons; in the working of the governor balls of steam engines constructed by Messrs. Boulton and Watt, and in the raising of coal and ore from the mines, for which purposes ropes had before been solely used at this manufactory. In all cases it has performed with the utmost safety, uniformity, and flexibility; so much so, that the prejudices of our workmen against chains are entirely done away, and they hoist the heaviest articles with more ease, and as great confidence of safety, as they would with the best ropes.

The same method is applicable, at a trifling expence, to all machines at present worked by ropes, or by chains, in the usual way: and all the common chains now in use, may be applied to it with equal facility.

With a view of ascertaining the relative flexibility of ropes and chains, I wedged an iron pulley, thirty-one and a half inches in diameter, on the spindle of the pinion of a crane of the following description, *viz.*

Barrel, 30 inches diameter.

Wheel, 64 teeth.

Pinion, 8 ditto.

Top block, with three pulleys of 12 inches diameter.

Bottom block, with 2 ditto. ditto.

To the large pulley I attached a small rope, for the purpose of suspending the weights in the hoisting of the different loads, and the results were as follow:

The crane was loaded with,			Took to hoist the loads when reefed with the chain in grooved pulleys. All the experiments were tried with the same grooved pulleys.			Ditto, when reefed with a half-worn tarred strand-laid rope $3\frac{1}{2}$ inches in circumference.			Ditto, when reefed with the chain promiscuously, as in the common way.		
		lbs.		lbs.			lbs.			lbs.	
First,	-	2000		63			74			80	
Second,	-	1000		32			39			41	
Third,	-	500		17			21			22	
Total 3500				112			134			143	

The flexibility is inversely as these momenta, and proves the superiority of chains; for (on the average of the trials with the chain in the grooves;

One pound raised - - - 31.25 lbs.

With a half-worn strand-laid tarred rope, three inches and a half in circumference - - - 26.11 ditto.

And with the chain in the usual way, only - - - 24.47 ditto.

It also appears (contrary to the general opinion,) that chains are safer than ropes; for it is an established axiom, that those bodies whose fibres are most in the direction of the strain, are the least liable to be pulled asunder; and in our examination of the properties of a rope, we find that the strands cross the direction of the strain in undulated lines,

and consequently prevent its uniform action thereon. A rope is subject to this inconvenience even when stretched in a direct line, but more particularly so when bent over a pulley, as in that position the upper section moving through a greater space than the under one, is acted upon by the whole strain; and hence the frequent breaking of ropes in bending over pulleys, from the double strain overloading the strands of which the upper section is formed.

The links of a chain are subject to the transverse strain, where they move in contact; but as such strain is in proportion to the length of the bearings, it must be very trifling. All the links having axes of their own, the chain moves simultaneously with the strain, and both are in consequence retained in continual equilibrio. A chain in grooves will therefore sustain as great a weight when bent

over a pulley, as it will in a direct line, and consequently is safer than a rope.

The Society for the encouragement of arts, manufactures, and commerce, having for many years past offered premiums for improvements in cranes, have therefore a large collection of models of different sorts. We have selected 3 of these, and have appropriated *Plate XX. Mechanics*, to the explanation of them. *Figs. 1 and 2*, are two elevations of a walking wheel crane laid before them by Mr. James White of Chevening, Kent, and for which he received a premium of 40 guineas in the year 1796. We have found it necessary to have new drawings made of this machine, as those published by the learned society are taken from the model left with them, and do not explain the manner in which the machine should be constructed.

Figs. 1 and 2, are two elevations of it at right angles to each other. *A A* is a large wheel, about 16 feet diameter, strongly framed and secured to its axis *E*, which is mounted upon pivots at its ends and inclined to the horizon in an angle of about 70 degrees, and consequently the plane of the wheel inclines 20 degrees. The rope of the crane is coiled round the axle and passes over a pulley *a*, (*fig. 1.*) to the gib of the crane, which is constructed in the usual method; *F* is a lever extending across the wheel and fixed at one end into an upright axis; *G H* is a short lever connected with an iron rod *e*, with a gripe *g*, which embraces part of the circumference of the wheel and prevents its turning, unless removed by pushing the lever *F*; *b* (*fig. 1.*) is a cord fastened to the gripe lever, and going over a pulley in the floor, having a weight suspended from it; this always gives the gripe a tendency to stop the wheel, and by the weight coming up to the pulley stops the gripe lever from going too far, when pressed by a man walking on the wheel. The wheel is turned by a man walking on the wheel and pushing the gripe lever *F*, so as to release the wheel which then turns (if the load be not too great) both by his weight and muscular exertion applied against the gripe lever.

The wheel is supposed to be erected in a warehouse, and an opening is made in the floor to allow the wheel to pass through. The man walks from the floor at *k*, up the wheel, which will always be at rest, unless he relieves it by pushing the lever *F*. The end, *l*, of the gripe is joined to a stout upright beam going from the floor to the ceiling of the room where the crane is erected, and the rest of the gripe should be hung by small cords from the ceiling to prevent its falling down and getting from its work.

The properties of this crane are as follow: its simplicity consisting of a mere wheel and axle. Secondly, its only friction, exclusive of the pulleys, is that on the two gudgeons of the shaft; and one of these supports the weight of the wheel, and of the man that works it, nearly in the direction of its point. Thirdly, it is durable, as is evident from the two properties above-mentioned. Fourthly, it is safe, for it cannot move but during the pleasure of the man, and while he is actually pressing on the gripe-lever. Fifthly, this crane admits of an almost infinite variety of different powers; and this variation is obtained without the least alteration of any part of the machine. If, in unloading a vessel, there should be found goods of every weight, from a few hundreds to a ton and upwards, the man that does the work will be able so to adapt his strength to each as to raise it in a space of time proportionate to its weight, he walking always with the same velocity as nature and his greatest ease may teach him. It is a great disadvantage in some cranes, that the smallest weight must be as long in rising

as the largest, unless the man turn or walk with a greater velocity, which tires him in still greater proportion.

In other cranes, perhaps, two or three different powers may be procured; to obtain which, some pinion must be shifted, or fresh handle, applied or resorted to. In this crane, on the contrary, if the labourer find his load so heavy as to permit him to ascend the wheel without its turning, let him only move a step or two toward the circumference, and he will be fully equal to the task. Again, if the load be so light, as scarcely to resist the action of his feet, and thus oblige him to run through so much space, as to tire him beyond necessity, let him move laterally towards the centre, and he will soon feel the place where his strength will suffer the least fatigue, by raising the load in question.

It has been before observed, that, if left alone, this crane will naturally reduce itself to a state of rest, even though a weight were suspended to it. The means will appear to be the gripe, or brake at the top, and its lever, which stretches across the diameter of the wheel, at the height of a man's breast, when in an attitude of treading the wheel to the best advantage.

The next crane of the Society's which we shall describe, is one for which Mr. John Braithwaite received their gold medal. The description published in the *third volume* of their Transactions, is as follows:

The frame, which is wholly of cast iron, is formed of two circles, held together by three screwed bars, and standing on four feet; the crane wheel, which is inclosed within the frame, consists of three concentric toothed face-wheels, joined together by strong bars, whose axle is the barrel, on which the rope is coiled; in the front of the face-wheels runs a shifting arbor; on this arbor is a pinion, which may be brought to work in the teeth of either of the face-wheels, and thereby the power employed at the winch may be applied to raise a greater or lesser weight occasionally. *A B C D E*, *figs. 3 and 4*, is a frame of cast iron; *F, G, H*, three concentric face-wheels, united together by the eight straight bars, *a, a, a*; *I K* a sliding arbor, on which is fixed a pinion *L*; *M* the winch or handle; *N* a stop, which, when lifted up, permits the sliding arbor to be moved backward or forward; but, when down, retains it in its proper place; *O* a pall, or stop, which prevents the crane running back, but may be discharged at pleasure; *P* the barrel on which the rope is coiled.

We think a great improvement might be made in this machine, by putting on the arbor, *I K*, three pinions, one for each wheel; they should all be put loose upon the arbor, but either of them may be easily fixed to turn with it by a sliding coupling iron; which will only admit of one being engaged at a time. The wheels might then be beveled, which are found, by experience, to work better than the face-wheels; and the sliding of the arbor obliges it to be of greater length than necessary, and more liable to be strained or bent; we have seen such a contrivance in other machines which acted very well.

Fig. 5, is a contrivance of Mr. Joseph Dixon, for which the Society presented him with 15 guineas in 1793, which he calls a preservative-wheel; it is intended to be applied within-side of an ordinary vertical wheel, where the men walk in the inside, to prevent the danger to which they are continually exposed, by the load being too great for them; the wheel then runs back, and throws them about in the wheel, and frequently kills them. *A E* is the axis, or spindle of the walking-wheel; the arms are mortised into it at *aa*; *E* is the part where the crane rope winds; *B, B*, are two wheels fixed on the axis, and having at their peripheries six pulleys,

over which ropes run, that are fastened at their extremities to two segments of circles C, C; these are united together by a wooden bar D, which the men are to lay hold of and suspend themselves by in case of danger.

This machine would completely obviate the danger to which the men who work in these wheels are exposed, but it would, at the same time, increase the danger to those employed in other parts, as the men within the wheel would, by hanging themselves to the bar D, remove all obstructions to the wheel's motion, and, without some other contrivance of a brake-lever, the wheel would run down so rapidly by the action of the load as to expose those at the gib, and other parts, to great danger.

Mr. Ferguson contrived a crane (already described) to remove the same defect, where the walking-wheel had a ring of cogs round its outside, working into a pinion, on whose axis was a brake and ratchet-wheel, with a winch at the end for the man who managed the brake to assist occasionally in raising the load. But the rapid motion of the circumference of these large wheels, in most cases, renders this contrivance inapplicable, unless a smaller cog-wheel was fixed upon the same axis with the walking-wheel.

Fig. 1, of Plate XXI. is a gib for a crane invented by Mr. Bramah, and described by him in *Nicholson's Journal*, 8vo. vol. viii. p. 99. The support for the gib is a hollow pipe or column, A, firmly fixed by a square flanch, bolted to beams in the ground, and the rope for the crane passes through this pillar. The gib of the crane has two sockets, *a, a*, fitting to the pillar, so that it can turn all round. A pulley, *b*, is fixed on the back of the gib and its edge hangs just over the centre of the column: *d* is the pulley at the end of the gib. The crane rope, after going over the pulleys *b, d*, passes down the column, and goes round another pulley, to convey it to the crane-work, which may be of any of the kinds we have described.

Fig. 2, is a very good kind of crane, as it requires no framing over it; it turns round upon a strong vertical beam, A B, moving between rollers fixed in the floor of the

wharf at B, and going down below that 12 or 14 feet, where it works on a pivot. The beams of the gib are mortised into the beam A B; the wheels are mounted in a frame formed by two cast iron crosses bolted to the beam, one on each side; the barrel is one foot diameter; the great wheel has 100 teeth, and is four feet diameter; the second wheel has 32 teeth; and the last pinion seven leaves. The winches can be applied to any of the wheels for different powers, when it is used on the barrel, or second wheel; the others are put out of gear by sliding their spindles endways. The barrel and pulleys should always be grooved, as in Mr. Smeaton's crane, where chains are used, though this is not sufficiently attended to by Mechanics.

Fig. 3, represents the tongs by which logs of timber are taken up with a crane, and the greater weight they bear the better they hold. *Figs. 4 and 5,* are two elevations of a crane by Mr. Valentine Gotlieb of Lambeth Marsh, London. The barrel, A, has a wheel fixed to it at each end; one, *a*, has 96 teeth, the other 90; *b* is an arbor with two pinions on it of eight teeth for the wheel 96, and another of 14 for the wheel 90; these pinions are at a smaller distance apart on their arbor than the two wheels, so that they cannot be both engaged to the wheel at once, and by sliding it an end either wheel and pinion may be used for different work; *e, f*, are two stops to hold it in either one; *h* is a fly on the same arbor *b*, and *e* the handle. The original part of the crane is the gib; it is a large beam, H, placed horizontally, and running upon a roller at *k*, and its other end kept down by another at *l*; it has a pulley at its outer end, over which the rope passes. The underside of the beam is cut into teeth, forming a rack, and a pinion of eight leaves, on the same arbor as the wheel *m*, moves the beam, so as to bring the goods suspended from its end into the house. H is the wall of the warehouse, and the wheels are supposed to be placed in the roof. The wheel *m*, and the fly wheel, have endless ropes going round them to work the crane by, in the room below, if necessary.

Crimson

CRIMSON, in *Dyeing*, is produced by various processes according to the nature of the substance employed, and the kind of stuff destined to receive the colour. Wool and silk are dyed either with cochineal or Brazil; with the former the colour is more fixed and permanent, and is called the true or fine crimson; Brazil gives a fine colour, but does not resist the action of the sun and air so well.

All the processes for dyeing wool crimson with cochineal may be reduced to two. Either the shade desired is given to cloth previously dyed scarlet, or the cloth is dyed crimson at once.

The natural colour of cochineal is crimson, and it affords this colour both with alum and the solution of tin, when its effects are not modified by the action of tartar, as has been shewn by Bancroft. When cloth therefore that has been dyed scarlet in the usual way is boiled in a solution of alum, the natural hue of the cochineal is restored, and the cloth becomes crimson. Alum, salts with earthy bases in general, the fixed and volatile alkalies all effect this change; the quantity necessary to produce any determinate shade, varies considerably with the nature of the water employed. Some which is loaded with earthy salts will answer the purpose without the addition of alum, or any other substance whatever.

Hellot tried soap, soda, and potash; all these substances produced the colour desired, but saddened it and gave it less lustre than when alum was employed. Ammonia, on the contrary, produced a very good effect; but it evaporates quickly from the bath and requires a considerable quantity. Hellot replaced the use of it, by adding equal quantities of muriate of ammonia, or common sal ammoniac, and potash; the ammonia was disengaged in the bath, and in this way the cloth instantly took a very bright colour. He asserts that the colour is so much heightened as to render less cochineal necessary. Mr. Poerner has given nearly the same process. He directs the cloth to be boiled an hour in a solution of common salt in the proportion of 2½ ounces to 1 lb. of wool, and to let the cloth remain in it 24 hours after it is become cool. A bath is prepared with 1 ounce of cochineal, 2 drams (gros) of tartar, and 2 ounces of solution of tin for every pound of cloth, and in this it is boiled one hour. When washed it is steeped in a vat, in which equal quantities of sal ammoniac and potash, in the proportion of 6 drams of each to a pound of cloth, have been previously dissolved; it is suffered to remain here 24 hours, frequently turning and moving it in the liquor. It is afterwards taken out and washed. The colour is a reddish crimson inclining to blue.

This mode of producing crimson by the action of alkalies or alum, is generally resorted to when cloth dyed scarlet has been stained or spotted by accident. These defects are thus remedied or rendered less glaring. Muriate of soda, or common salt, has also the property of converting scarlet to crimson, and has long been used for this purpose in Languedoc, according to the testimony of Hellot.

To dye crimson at once, a solution of two ounces and a half of alum, and an ounce and a half of tartar to every pound of cloth, is used for the boiling; the cloth is afterwards dyed with 1 ounce of cochineal. Solution of tin is

commonly added, but in less proportion than for scarlet. The processes employed vary greatly according as the shade required is deeper or lighter, or more or less removed from scarlet. Some use common salt for the boiling.

Mr. Poerner directs the boiling to be made with 3 ounces of common salt and 3 of alum, to 1 pound of cloth, and after suffering it to remain 24 hours in the solution after cooling, to boil one hour in a bath composed of 1 ounce of cochineal, 2 drams of tartar, and 2 ounces of solution of tin. The cloth takes a reddish crimson.

A bright reddish crimson of very agreeable hue may be obtained by boiling 1 lb. of cloth a full hour in a bath prepared with 3½ ounces of alum and 2½ ounces of tartar, suffering it to remain 24 hours in the liquor after cooling. Then boil an hour and a half in a bath composed of 1 ounce of cochineal only, without any other ingredient. If this cloth be steeped 24 hours in a cold solution of 1½ ounce of sal ammoniac, and 1½ ounce of potash in 20 lbs. of water, the colour becomes deeper, and another shade of crimson is by this means obtained.

Archil and potash are frequently used for saddening crimsons and giving them more bloom, but the hue thus imparted soon vanishes.

The boiling for crimson is sometimes made after a scarlet dyeing, by adding alum and tartar to the bath, and some particular shades of crimson are said to possess more bloom when dyed this way, than when fresh baths are used.

Crimsons in half grain are sometimes dyed by substituting madder for half the quantity of the cochineal, following in general the same processes as for the grain crimson. Other proportions of madder may be used instead of half, according to the effect required.

The colour produced by Brazil is not so permanent on wool as cochineal, it is nevertheless employed. The cloth is boiled in a solution of alum, to which a fourth of its weight, or even less of tartar is added. A greater proportion of tartar inclines the colour too much to the scarlet or yellow hue.

The cloth thus impregnated should remain several days in a cool place; after which it is dyed by boiling gently in Brazil liquor. The colouring matter which is first deposited does not yield so fine a colour, the coarsest goods should therefore be passed through the bath first, and afterwards the finer ones. In this way a colour is obtained which stands the action of the air tolerably well.

Mr. Poerner directs 1 lb. of cloth prepared with 5 ounces of alum, and 1 ounce of tartar, to be boiled one hour in a bath containing 6 ounces of Brazil, and 6 ounces of alum. The cloth acquires a deep brick red. When steeped 24 hours in a cold solution of potash, it becomes a fine reddish crimson. By preparing the cloth with alum and tartar, Mr. Poerner observes that very good and useful colours may be obtained from Brazil, which are deeper and richer than those obtained on cloth prepared with alum, tartar, and solution of tin, or with tartar and solution of tin without alum. By varying the proportion of the ingredients, and still more by the action of potash and sal ammoniac, these shades of crimson may be greatly modified. Colours obtain-

ed from Brazil may thus be rendered tolerably permanent, yet they are not comparable in this respect with those obtained from cochineal or madder. A bloom is sometimes given to madder colours by passing them through a decoction of Brazil, but this slight tinge soon fades and perishes.

Mr. Guldiche gives a process, by which he pretends that fine and more permanent colours are obtained than by those in general use. He directs pure vinegar, or *aceto-citric acid*, or aqua regia, to be poured on Brazil rasped or chipped, till it is covered with the liquor; the mixture to be well shaken, then left to settle for 24 hours, after which it must be decanted, filtered, and kept for use. On the residuum, fresh water or vegetable acid is to be poured, and this to be repeated till all the colouring matter is extracted, when the wood will be found to be black. All these liquors are then to be mixed together for use.

The stuff having been prepared with a slight galling of sumac, or white galls, is slightly alumed. After rinsing, it is entered wet into a bath prepared as follows: Some of the acid solution of Brazil is diluted with water proportionate to the quantity of stuff, or the shade of colour to be given. When this is so hot that the hand will just bear it, solution of tin is poured in till it is of a fire colour: it is then stirred and the stuff entered. In half an hour it is taken out and washed. The remainder of the bath may be used for lighter shades, but those stuffs only must be galled that are for deep ones. The *aceto-citric acid*, as it is called by Berthollet, is a liquor of which Mr. Guldiche makes great use in dyeing under the name of vegetable acid spirit, which he prepares in the following manner: He takes any quantity of lemons; those of which the rind is rotten will do, removes the peel and the skin that adheres to it, and slices them into a vessel, which should not be made of wood. He sprinkles them with a quantity of good vinegar, and then squeezes out the liquor through a flannel by means of a press, and filters the expressed liquor through paper. It may be used with success in this state, but it is apt to grow mouldy and the acid is watery. In order therefore that it may keep, and not dilute the baths into which is put, he directs it to be purified and concentrated as follows: The liquor is to be exposed to the sun till a sediment forms and it becomes clear, it is then to be filtered and distilled on the sand bath. The receiver is to be changed when the liquor that drops becomes acid, and the distillation continued till oily streaks are perceptible in the neck of the retort.

The acid found in the receiver is to be kept for use.

On the foregoing process for obtaining *aceto-citric acid*, we shall observe that if the acid be used in its recent state, as expressed from the lemons, it is indeed a mixture of citric and acetous acid, but the rectified and concentrated spirit of Mr. Guldiche is, after all, nothing but distilled vinegar. Citric acid will not rise in distillation; it may be decomposed by heat, but cannot be driven on like acetous acid; this process of rectification is therefore a separation of the acid of the lemons from the vinegar they were sprinkled with, and proves the inutility of one of the ingredients at least of this composition. Of the efficacy of galls in rendering the colouring matter of Brazil more permanent there can be little doubt, but it has a tendency to debase the colour, and it is with reason, that Mr. Guldiche observes that the galling should be employed only for the deeper shades.

Silk acquires from cochineal a colour which is distinguished from the false crimson obtained by means of Brazil.

Silk intended for cochineal crimson ought not to be boiled with more than 20lb. of soap to 100 of silk, as the yellow cast which silk has when imperfectly scoured is favourable to this colour. It is sometimes imparted to it

by a slight tinge of annatto, when white silk is to be dyed crimson.

When the silk is well cleaned from the soap by washing, it is soaked in a strong solution of alum, in which it is generally left all night, and next day is wrung, washed, and twice beetled at the river.

The bath is prepared as follows: Into the dyeing vessel, half, or two thirds filled with boiling water, from one to two ounces of pounded white galls are thrown in for every pound of silk. After boiling a few minutes, two ounces of cochineal or more, according to the strength and fulness of the shade required, are added for every pound of silk, and for every pound of cochineal, one ounce of tartar. When this is dissolved, an equal weight of the solution of tin is added; the ingredients are all well stirred, and the bath filled up with cold water. The proportion is generally about eight or ten quarts to every pound of silk. In this the silk is entered and worked till it appears quite uniform in colour; the fire is then increased, and the bath made to boil two hours, turning the silk from time to time. The fire is then withdrawn, and the silk left in the bath a few hours longer. It is then washed at the river, twice beetled, wrung, and dried. The solution of tin for this process ought to contain more tin than is used in the composition for scarlet, otherwise the colour is too bright, and not sufficiently full and deep. Macquer directs the solution to be made with one pound of nitric acid, two ounces of sal ammoniac, two ounces of tin, and twelve of water.

If the colour is to be faddened, the silk after washing is passed through a solution of sulphate of iron, more or less strong, according to the shade required: if the crimson should have a tinge of yellow, a greater or less proportion of the decoction of fustic must be added to the solution.

White galls are preferred, because the black or blue galls debase the colour of the cochineal; and even white, when used in too great a quantity, dull the crimson very much. Macquer pretends that the galls serve only to increase the weight of the silk; their general effect, however, is that of giving greater permanency to the colours, and in crimsons of the deeper shades their use is indispensable.

The quantity of solution of tin employed in the foregoing process is very small. If used in the bath in the same proportion as for dyeing wool scarlet, the silk would lose its lustre, and acquire but a faint colour. Macquer and Scheffer have however each published processes for dyeing silk rose or poppy colour, which differ only in a few particulars from the ordinary mode of dyeing scarlet, the solution of tin being employed cold to avoid its strong action on the silk.

In the process which Macquer published in 1768, the solution is prepared by adding three ounces of tin by little at a time, to a mixture of four ounces of nitric, and two of muriatic acids. When the solution is finished, 6lbs. of silk that have already had a slight ground of annatto, are immersed, and remain in it half an hour. It is then wrung and washed till it no longer renders the water turbid. It is dyed with four ounces of cochineal, and one ounce of tartar, for every pound of silk. These are boiled up in water, and afterwards cooled down till the hand can bear the heat. The silk is then entered, and the fire increased; after boiling one minute it is withdrawn and washed. By this process the silk has acquired an increase of one fourth of its weight. Its colour resists soap, and is much more permanent than that which *Carthamus* affords.

In 1751, Scheffer published a description of the following process. He dissolved one ounce of tin in a mixture of

four ounces of nitric acid, and one of common salt. The solution was diluted with twice its quantity of water, and the silk steeped in it 24 hours. When withdrawn it was washed till the water no longer appeared milky, and dyed with four fifths of its weight of cochineal in a small quantity of water. The bath retains a considerable portion of colouring matter which may serve for dyeing silk a lighter shade, or even for dyeing crimson by the ordinary process. It may be used also for dyeing wool.

Scheffer describes the following varieties of his process for obtaining different shades. If the silk be wrung out of the solution of tin, left all night in a cold solution of one ounce of alum in a quart of water, wrung, dried, washed, and afterwards dyed with cochineal, it will take only a pale poppy colour. If the silk be steeped twelve hours in the solution of tin diluted with eight parts of water, and then left all night in the solution of alum, washed, dried, and passed through two baths of cochineal as before, adding to the second bath a little sulphuric acid, the colour will be a fine poppy red.

In the experiments made by Berthollet on this subject, the solution of tin, which answered best for dyeing silk, is that which he has directed for the scarlet dye, and is made by dissolving slowly in one pound of nitric acid, two ounces of tin, and two ounces of sal ammoniac: the salt to be dissolved first, and the tin added afterwards in small portions at a time, stirring it frequently to incorporate the solution fully. When finished and decanted from the black sediment which is deposited, it is diluted with one fourth of its weight of water. The nitric acid employed should be of the strength of 30° of the hydrometer of Beaumé, which corresponds with a specific gravity of about 1.26.

Solutions containing a greater proportion of tin gave deeper shades. The colour obtained by the above, was a fine cherry colour sufficiently bright.

Brazil wood is used for dyeing silk what is called *false crimson*, to distinguish it from that produced by means of cochineal, or *grain crimson*, which is much more permanent. Vinegar is used to distinguish the true colour from the false, but this proof is fallacious, since the Brazil crimson dyed with the solution of tin, resists the action of vinegar like cochineal, though that dyed with alum does not.

Silk intended for this crimson, should be boiled with soap in the proportion of twenty pounds to a hundred of silk, and afterwards alumed. Less alum is required for this than for grain crimson. After rinsing in the river, it is passed through a bath more or less charged with the decoction of Brazil according to the shade required. If water, free from earthy salts, be used, the colour is too red for crimson; the proper hue is given to it by passing the silk through a slight alkaline solution, or by adding a little alkali to the bath.

Working the silk in hard water till it has acquired the proper shade, will answer the same purpose.

Logwood liquor may be added to the Brazil, to deepen the shade of crimson, and a little alkali used with it also when the shade desired requires it.

There is the same objection to the use of the solution of tin in dyeing silk crimson with Brazil as with cochineal; silk has not that powerful attraction for the colouring matter combined with tin that wool has; the greater part therefore separates and contracts no union with the stuff. Bergman, however, remarks that the colours imparted to silk by different dye woods, may be much improved by steeping the silk in a cold solution of tin. A strong decoction of Brazil, says he, gives to yellow silk prepared in this way a scarlet colour inferior indeed to that of cochineal, but finer and more permanent than if it be steeped in alum only, and as

capable of standing the proof by vinegar as crimson or poppy in grain. Mr. Gühliche describes a process, in which he uses solution of tin in the bath to give silk a fire colour. He directs the silk to be galled with a solution of galls in white wine, asserting that an astringent solution thus made preserves the brightness required in silks much better than one prepared with water. With this solution he mixes water till it has acquired a yellow colour, and impregnates the silk well with it, leaving it to steep cold for several hours. He then presses out the liquor strongly, but without rinsing the silk which he dries, and afterwards soaks for twelve hours in a solution of alum, containing four ounces for every pound of silk. The silk taken out of the alum water is wrung, and entered wet into a bath of Brazil, after adding to it an ounce of solution of tin. The remainder of the bath may be exhausted for lighter shades. If the colour be required more approaching to orange, the silk is not to be galled, but to be alumed cold with two ounces of alum to the pound of silk, after which it must be dyed orange with annatto, without boiling, and before it dries dyed in the Brazil bath. The author confesses that these colours, particularly the latter, are not very permanent. For rose colours he omits the galling, and for the aluming uses only two ounces of alum to the pound of silk. For light shades he recommends the solution of alum to be decanted from the sediment that may have been deposited, and prefers dyeing them cold, using a bath richer in colour. The silk is to be taken out as soon as it has acquired the proper tint, and the bath may be exhausted for other shades. With these precautions he assures us, that fine colours of tolerable permanency may be obtained.

The crimson imparted to cotton or linen by cochineal and Brazil, has little solidity, and is on that account but little used, more especially as madder imparts to these substances, properly prepared, one of the most beautiful and permanent colours which the art of dyeing can produce.

As this however is not the place in which to enter into a detail of the operations of the Turkey or Adrianople red, which we purpose to treat at large under another head, we shall give some account of the processes that have been proposed and practised with more or less success for producing a fine crimson colour upon cotton by means of cochineal and Brazil.

Mr. Poerner has made many experiments with different mordants, as alum, solution of tin, sal ammoniac, potash &c. for dyeing cotton with Brazil, used either in the bath or in the preparation of the cotton. He could not produce a colour, however, that would stand washing with soap, though some would stand the action of the air and washing with simple water very well. He recommends cotton thus dyed, to be dried in the shade.

Mr. Berthollet received from Mr. Brown the following process for dyeing cotton a crimson colour, which is used by some manufacturers.

A solution of tin is prepared in the proportion of nitric acid two pounds, muriatic acid one pound, tin eight ounces and water one pound. The liquids being well mixed, the tin is added by little and little. For a piece of cotton velvet weighing fifteen or sixteen pounds, a bath is prepared consisting of boiling water four parts, strong decoctions of galls two parts. Having raked up the bath, the piece is entered and worked for half an hour, and left to soak two hours, when it is taken out and left to drain. Another bath prepared with three buckets of boiling water, and one of decoction of Brazil wood, also boiling, is to be raked up and the piece worked in it an hour. This bath is to be thrown away, the vessel washed out and then filled with a pure de-

coction of the wood, in which the piece is to be worked half an hour, and then raised on the winch. A bath of very clear river water, with a quart of solution of tin, being prepared and raked, the piece is to be worked in it a quarter of an hour. It is then wound on the winch, and set on the vessel containing the decoction of Brazil, one sixteenth of which is to be taken out and replaced by an equal quantity of boiling decoction. This being raked, the piece is worked in it half an hour, wound on the winch and carried back to the vessel containing the solution of tin. These operations are performed alternately six or eight times, observing each time to take out a sixteenth of the bath of Brazil wood, and replace it with an equal quantity of boiling decoction of the same wood, to rake the bath of composition each time, and to finish the dyeing with the latter. The piece is to be washed in the river, and dried in a dark place.

With the aluminous mordant cotton takes a full and tolerably bright crimson from Brazil, the permanency of which is considerably increased by previously subjecting the cloth to the operation of galling. The printer's mordant prepared with acetite of lead and alum, is best for this purpose. When used diluted, the shades of crimson and rose colour are very delicate, but so fugacious as not to support the action of the sun and air unimpaired a single day. Sumac used in the bath along with Brazil contributes greatly to its fixity; the stronger shades dyed this way support the action of the air tolerably well, and have greatly the appearance of a madder red.

Cochineal is little used for dyeing cotton and linen, since the colour is much less permanent than that obtained from madder. Scheffer however has described a process which may be employed. The cotton is to be steeped 24 hours in a cold solution of tin, it is then wrung, washed, and boiled a quarter of an hour with four-sixths of its weight of cochineal. It takes a light red, and resists the sun and air for a time, but not soap. Little use appears to have been made of this process of Scheffer, though it is probable that Dr. Berkenhout availed himself of it some years afterwards, when he pretended to have discovered the means of dyeing scarlet crimson, and other colours upon cotton and linen; and though his process was not materially different from Scheffer's, nor in any respect preferable, he obtained 5000 l. from the British government, as a reward for making it public.

As it excited considerable interest and some contention at the time, we shall present our readers with the following detail of the process, as it was communicated by order of the lords of the treasury to the company of dyers in the city of London, Aug. 16th. 1779. *viz.*

"Cotton or linen, either in yarn or piece, should be perfectly wet with hot water, and then wrung out, as is the common practice.

"This being done, it must be perfectly soaked in a solution of tin diluted with an equal quantity of clear soft water.

"The cotton or linen being so far prepared, must be wrung out, but not forcibly; it is then to be nearly dried, laying horizontally upon a hurdle with a double linen sheet between them, and covered with the same.

"The solution of tin being for scarlet, must be made of nitrous acid, and not of aquafortis; but for crimson, aquafortis must be used, and the bloom is to be given after it comes out of the dye, by a small quantity of sal ammoniac and pearl ashes dissolved perfectly in warm water, but this water must not be more than milk warm.

"The colouring vat for the scarlet or crimson is simply

cochineal in water no hotter than the hand will bear, and as vegetable matter receives only the small particles of the colour from the nature of its pores, two ounces to a pound of the materials dyed may be necessary: but cotton or linen fresh prepared, will draw from the same vat, heated as before, all the inferior shades from scarlet and crimson, and if any colour still remains in the vat, it may be taken out entirely, by wool prepared in the usual manner.

"The same preparation of tin serves for the green and yellows, with the same materials only that are employed by dyers, except the best yellow, which is produced from turmeric.

"It is necessary to observe, that after the preparation has been made use of for scarlet or crimson, the residue continues sufficiently strong for greens or yellows, even after it has been kept a considerable time.

"N. B. To make the best solution of tin with nitrous acid, it is necessary to have the strong smoking spirit, to which an equal quantity of the purest river water must be added, and the proportions of the following ingredients are to the weight of spirits $\frac{1}{8}$ sal ammoniac, $\frac{1}{2}$ refined nitre, dissolved by little at a time. In this aqua regia, dissolve $\frac{1}{4}$ of granulated tin also by small quantities, to prevent too great an ebullition which would weaken the solution considerably. The ingredients and proportions are the same when a solution is to be made with aquafortis, but that spirit in general will not bear any water when a perfect solution is intended."

Besides the fugitive nature of the colour dyed by the above process, it was found that the texture of the cloth was considerably injured, and it was soon laid aside, or rather was never adopted. If, notwithstanding the want of sufficient permanency, however, the colour which cochineal affords, should still be required; the best way of producing it, according to Dr. Bancroft, is to soak the cotton (previously moistened) about half an hour in a diluted solution of murio-sulphate of tin; then wring or press out the superfluous part of the solution, and plunge the cotton into water, in which as much, or nearly as much clean potash has been dissolved as will neutralize the acid still adhering to the cotton, so as to precipitate the oxyd of tin, and cause it to be more copiously deposited or fixed in the cloth, which being afterwards rinsed in clean water may be dyed, with cochineal in the usual way. A full bright colour may be given to cotton in this way, which will bear a few slight washings with soap, and a considerable degree of exposure to air. The murio-sulphate of tin, on which Dr. Bancroft lays great stress, as well for the above process as for dyeing silk crimson, is prepared by dissolving 14 ounces of tin in a mixture of two pounds of oil of vitriol with three of muriatic acid. The muriatic acid should be first poured upon the granulated tin in a large glass vessel, and the oil of vitriol afterwards added slowly; and these acids mixed should be left to saturate themselves with tin, which they will do in time without artificial heat; but the solution will be rapidly promoted by a sand heat.

Under the head of cochineal we have given a short account of its use in calico-printing in dyeing crimson, to which we must refer our readers as well as to the article COLOUR for other details connected with the subject. The colours produced from madder with the aluminous mordant in the ordinary processes of this art, strictly speaking, belong not to the class of crimson, yet by repeated brauning, boiling in soap or alkalies, the yellow or faun coloured principle which this root contains, may be nearly extracted, and tolerable crimsons obtained. The addition of a small quantity of solution of copper to the acetite of aluminine, gives the

colour a crimson hue of no great lustre, but very permanent.

The following process by Mr. Grouse, affords a colour of less intensity indeed, and solidity, but scarcely inferior in beauty, to the Adrianople red.

Prepare a mordant by dissolving 4 lbs. of acetite of lead, and 4 lbs. of alum in a gallon of pure water, and after decanting the supernatant clear solution from the precipitate which forms, thicken it with gum to the consistency required. If the work requires the mordant to be *lightened*, add a little infusion of cochineal till it is sufficiently tinged to enable the printer to observe the progress of his work. Keep the goods from four to six days after printing, in a warm place, to facilitate the liberation of the acid; rinse them five minutes in a copper of water at 120°, with two good spade-fuls of cow dung, after which wash and rinse them in clean water several hours, alternately winching, washing, and suffering them to steep in the river. Lastly, winch five minutes in a clean hot water copper at 120°, and after rinsing and washing again in the river, dye them as follows. Into a dye copper of 300 gallons capacity three parts filled with clean water, free from all accidental impurities, and not discoloured either by rain or floods, put 20 lbs. of the best crop madder, and 60 lbs. of good sweet bran. Mix well, and bring them up quickly to a boil, and

keep them in a state of ebullition 20 minutes. Add cold water sufficient to take the copper off the boil, then enter two pieces, winching them briskly and keeping them down with the copper stick the whole time they are in. Bring the copper up to a boil again, and in 8 or 10 minutes, according as the shade required, the goods will have acquired their full colour. Enter two more pieces after these are withdrawn, and keep them in a few minutes longer; they will be scarcely inferior to the former, but as the copper becomes exhausted, every succeeding set will acquire less colouring matter than the preceding, and if the operation be continued upon several sets without refreshing the copper, the last will acquire only a pale but delicate rose colour. If the whole are required to be full deep colours, the copper must be supplied with a regular charge of bran and madder after every second set, but to exhaust the bath fully, and proceed with due regard to economy, the strong colours should be dyed first, and the pale and more delicate shades afterwards.

Wash them well after dyeing, and bran them at a boil. The colour improves much by this last operation, which may be repeated on the stronger shades till the colour has acquired its proper hue, and the whites are good. See Madder.

Crucible

CRUCIBLE, in *Chemistry*. Crucibles are small vessels made of earthenware metal, or other materials, employed by chemists in operations with the naked fire, such as fusions and reductions of metallic ores in the small way, vitrifications of earthy mixtures, calcinations, &c. &c. The construction of these vessels is of no small importance to the chemist; and many observations will suggest themselves with regard to their selection and proper use.

1. *Of earthen crucibles.* Formerly, when chemists made their own crucibles and fire-pots, the subject engaged much of the attention of such eminent practical operators, as Pott, Glauber, Agricola, Cramer, &c. and more lately a considerable improvement has been made by that eminent scientific manufacturer, the late Mr. Wedgewood.

A pottery ware, which should unite all the requisites for a good crucible, should be infusible at almost any heat, close and compact in texture, so as to retain saline and metallic fluxes for a considerable time, without being materially acted on by them, or allowing them to pass through; and should be able to bear sudden changes of temperature, without cracking or splitting. It is found, however, that

all these requisites are incompatible in the same ware; so that a selection must be made, according to the intended use.

For enduring the most intense heat, without fusion, the hard, coarse, brown crucibles, originally made at Waldenburg, in Hesse, have long been the most esteemed. They are manufactured, according to Pott, by mixing a very refractory clay with a coarse sand, the finer parts of which have been separated by the sieve and rejected. These vessels are not turned on the potter's lathe, as this would require a considerable portion of water to bring them to the requisite degree of plasticity, but the mass is barely moistened, and is then fashioned into the proper shape, by being strongly rammed into an iron mould. The crucibles are then very slowly dried and baked. The genuine Hessian crucibles are extremely hard, and (unless filled with any substance that acts as a powerful flux) they are only softened, but not melted down, by a heat of sufficient intensity for any chemical operation. Though the coarseness of their texture tends to render them porous, this defect is counteracted, in a great measure, by the very small quantity of water used in making them, and the consequent smallness of the

shrinkage whilst drying; and their coarseness enables them to bear a pretty rapid heating and cooling without cracking.

The ordinary brown crucible ware used in this country, is whiter and finer than the Hessian, but is softer, more crumbly, and much more porous; so that litharge, when in fusion at a full red heat, runs through this ware nearly as easily as water soaks through a sponge. It is also more fusible than the Hessian, though it is sufficiently refractory for most purposes.

The most infusible material for fire-pots that is known, and which resists the operation of saline fluxes for the longest time, is a mixture of burnt and unburnt clay; and this is the composition of the large pots or crucibles used in glass-making. The peculiar advantage of this mixture is, in substituting baked clay to sand, or any other silicious earth, and thus increasing the proportion of alumine, which is an earth of difficult solution in fluxes, and diminishing that of silica, which is more soluble.

Crucibles intended for the fusion of metals are much improved by a mixture of plumbago. This substance is infusible *per se*, and being protected from the action of the air by being involved in the clay, its carbonaceous ingredient escapes combustion. It has the additional advantage of having no affinity whatever with the earths, and, therefore, does not dispose them to fusion; and the unctuous softness of this material gives a great smoothness to the surface of the crucible, which prevents it from detaining any portion of the melted material when poured out. The black-lead ware will bear sudden heating and cooling better than any other; and it is so soft, that it may readily be sawed or cut with a jagged knife, whereby the chemist may easily fit himself with stoppers, covers, &c.; but its extreme porosity renders it unfit to retain any kind of saline flux.

The useful fire-ware invented by Mr. Wedgwood is a very fine, hard, close-grained porcelain biscuit, made of very pure clay and silica, which are brought to extremely fine powder before they are worked. This gives a closeness of texture superior to any other pottery; so that crucibles made of it will long retain saline fluxes; and retorts will serve for the distillation of the most corrosive liquors, without requiring any glazing. Experience has shewn, however, that no kind of earthenware remains impervious to air, when very strongly heated. The great inconvenience attending the Wedgwood fire-pot ware is, its extreme liability to crack whilst heating or cooling, which is owing to its porcellaneous hardness, and the closeness of its texture. This inconvenience is, in some measure, remedied, by giving the crucible a slight coating of loam or clay.

It is often required, in chemical operations, to line the inside of a crucible with charcoal; as, for example, in the reduction of many of the simple metallic oxyds, or carbonated oxyds, such as the oxyds of manganese, copper, or lead, and for other purposes. This is sometimes done by cutting down a piece of charcoal to fit the cavity of the crucible, and then scooping a hollow in the charcoal; but it is a better and more speedy way to mix up some charcoal powder with a very little linseed meal, to moisten the mass just sufficient to make a slightly adhesive mass to line the crucible with it, and to dry it in a red heat, by which the volatile parts of the linseed fly off, and a sufficiently firm

charcoal is left.

The form of the ordinary earthen crucibles is round, or three-cornered, or sometimes barrel-shaped; and they are usually furnished with stoppers of the same material, with a small hole through the top, opening obliquely, to allow the escape of any vapour, when the joining is closed by lute, and at the same time to prevent any of the dust of the fuel from falling in. As the lower part of the crucible would escape the greatest heat of the furnace, if put immediately upon the bars, and would be liable to crack by the current of cold air, the crucible is generally set on a solid earthen stand, which raises it an inch or two from the grate. The lid of the crucible may be luted on by a mixture of clay and sand; or, if it is required to be quite impervious, a mixture of pipe-clay, with about a tenth of glass of borax, may be employed, which, in a red heat, consolidates into a semi-fused tenacious mass.

Crucibles are also made of silver, iron, and platina. A silver crucible is almost indispensable in the analysis of earths and stones when they require to be first treated with caustic alkali; for, if earthen vessels are used for this purpose, the alkali acts also on the substance of the crucible, and thus much confusion is introduced in the process; whereas pure silver is not in any way acted on by alkali. The silver employed for this purpose should be freed from alloy, either by cupellation, or by being recovered from luna cornea. Silver, when perfectly pure, and laminated into a thin plate, is fusible at a full red heat, not more intense than can be made in a common fire; so that a crucible of this material will but just bear the heat required for the perfect fusion of the fixed alkalis, and will hardly retain the melted alkali for any great length of time. It is found, however, that this heat is by no means necessary, for most earths are completely *resolved*, or rendered soluble in water or acid, by previous ignition with alkali, for about an hour, in a heat short of fusion.

When a very strong heat is required to be given to the mixture of alkali and earths, chemists sometimes employ an iron crucible, previously cleaned and smoothed on the inside, which is often found very useful for other purposes.

Lastly, we may mention platina as a material for crucibles, which has been found of such singular utility for a vast variety of uses, that it is almost indispensable to the analytical chemist. Platina has the advantage of bearing the utmost intensity of heat without fusion, and not being in any degree oxydized by exposure to air, the smoothness and polish of the surface remain uninjured; so that substances which are heated in it may be detached with great ease and accuracy. There are few substances that act on platina; so that most operations that require heat may be performed safely in vessels made of this valuable metal: the particular mode of working it will be mentioned under the article PLATINA. It unfortunately happens, however, that the alkalis, when in strong fusion, dissolve a sensible portion of this metal; and hence it is not equally valuable with pure silver under these circumstances. When platina crucibles are strongly heated, in contact with coak or coal, they should be inclosed loosely in crucibles of earthenware, otherwise the vitreous slag of the coal is apt to adhere strongly to the outside of the platina vessel, and cannot be got off without much difficulty.

Cumberland

CUMBERLAND, in *Geography*, a maritime county in the northern part of England, bordering Scotland, is bounded on the west by the Irish Sea, into which its western coast projects, somewhat in the form of a bow, to an extent of nearly 70 miles; on the north it is separated from Scotland by Solway Frith, the Scots Dyke, and the river Liddal; its eastern side is skirted by the counties of Northumberland and Durham, the dividing limits being mostly artificial; to the south its boundaries are Westmoreland and Lancashire: from the former it is partly separated by Ulls-water and the river Eamont, and from the latter by the river Duddon. The greatest extent of the county is about 80 miles, but its mean length not more than 60; its general breadth is nearly 35; and its circumference 224. It contains 970,000 acres: of these 342,000 comprise the mountainous districts; 470,000 are enclosed, and chiefly under cultivation; 150,000 are in low commons, capable of improvement; and 8000 in lakes and waters. Cumberland is divided into five wards, synonymous with the hundreds in other counties; but so called here, from the inhabitants of each division being formerly obliged to keep watch or ward against the irruptions of the Scots, in times of warfare. It contains one city, Carlisle, 17 market-towns, 112 parishes, 22,445 houses, and 117,230 inhabitants. The ward of Allerdale, above Darwent, is in the diocese of Chester; all the other part of the county is in that of Carlisle. The representatives in parliament

are six, *viz.* two for the county, two for Carlisle, and two for Cockermouth. Cumberland pays one part of the land-tax, and provides 200 men for the militia.

The surface of the county is extremely irregular and broken. The south-western district exhibits a gigantic combination of lofty, rugged, and rocky mountains, promiscuously thrown together, but enclosing many beautiful, though narrow, vallies, as well as fine lakes, rivers, and some extensive woodlands. On the eastern confines, another range of hills stretches along to Scotland, but possesses much less picturesque beauty than the former. In the front of this last assemblage, a considerably broad tract of low ground extends the whole length, unobstructed by any high mounts, partly cultivated, partly heathy common, and watered by the Eden, and numerous brooks and rivulets. This tract becomes very extensive before it reaches Carlisle; stretching across the county to Wigton, and thence towards Workington, including all the northern part of the county. Along the western shore there is a strip of cultivated land, from two to four or five miles in width. The woodlands are but few; and the general appearance of the county is bleak and naked, from the extensive moors which so frequently present themselves to the eye of the traveller. The soils of this district are exceedingly various, but have been classed under the divisions of fertile clays, or strong rich loams, which occupy

but a small portion of the county, and are chiefly appropriated to the growth of wheat; dry loams, including the different degrees from the rich brown loams to the light sandy soils, and occupying the greater portion of the land; wet loam, generally on a clay bottom, and adapted to grazing; and black peat-earth, which is very prevalent in the mountainous districts, and particularly those adjoining Northumberland and Durham. The enclosed grounds are kept free from moles by an excellent practice observed in the different parishes, of hiring persons to destroy them for a term of years, at a certain annual salary, which is raised like the regular parochial taxes, and does not exceed an halfpenny *per* acre.

The buildings of this county are chiefly of stone, except in the market-towns, where the houses are generally of brick; and near the borders of Scotland, where they are mostly constructed with clay or mud. Most of the old farm-houses, cottages, and out-houses, are thatched with straw, and the stones of the walls laid with clay instead of mortar; but the more modern buildings are generally covered with slate, and their walls cemented with lime: in those districts, however, where clay or mud walls prevail, the advances of modern improvements are admitted with some reluctance; the people considering them as an expensive and unnecessary luxury. Many of the houses are covered with a very fine blue slate, the best kinds of which are procured in Borrowdale.

The principal manufactures of Cumberland are the spinning and weaving of cotton into calicoes, corderoys, and other articles; and the printing of cotton. The former has not been many years introduced: it was first planted at Dalton, and soon extended to Carlisle, Warwick-Bridge, Corby, Comerisdale, and a few more places. The seat of cotton-printing is at Carlisle, the population of which place has thereby been much increased. In some of the market-towns are small manufactories of checks and coarse linens. At Egremont eighteen looms are employed in the manufacture of sail-cloth; and at Whitehaven, where it was only introduced in 1786, several hundred hands are employed in the different branches of the same manufacture. Three or four paper-mills are employed in different parts of the county; a manufactory of coarse earthen ware has been long carried on near Dearham; and near Workington are the Seaton iron-works, which employ several hundred workmen. Many private families knit and spin their own stockings; and every village is supplied with a weaver or two, who weave their home-made cloth.

The mineralogical substances of Cumberland are extremely rich and variegated, and exist in such abundance in the different parts of the county, that a description of the whole would, of itself, constitute a work of considerable magnitude. In the calcareous genus is limestone, of various colours, texture, and hardness. The quarries at Overend contain impressions of many kinds of shells, with ammonizæ, entrochi, and afteriz; and a great variety of marine exuviz are found in the limestone on the moors near Gisland Spa. Marble, with shells in it, of a brownish colour, is met with at Little Stainton and Dacre; dusky-green, veined with white, at Crofs-fell; yellowish, grey, lead-colour, and brown, with or without shells, on the banks of the Peteril; and blueish-black, clouded with lead-grey, veined and spotted with white, hard, free from cracks, and admitting of a fine polish, near Kirkofwald. Beautiful specimens of spar of various colours, amorphous, and crystallized in different forms, are found in the lead mines of Aldston-Moor; and, since the study of mineralogy has become fashionable, have been sold for considerable sums. In the mines between

Kefwick and Aldston it has been met with, crystallized in hexagonal prisms, terminated at one end by a pyramid. Gypsum is found in many parts of the county: its colour is mostly white, veined, clouded, and spotted with red; sometimes brown and grey; of compact, even fracture. It frequently, however, exhibits a considerable variety of appearance, even in the same quarry; and at Newbiggen is met with not only compact, but splintery, fibrous, foliated, and crystallized: in the latter state, the crystals are pure and colourless, arrow-headed, and irregularly disposed, forming the resemblance of a cock's-comb. It lies embedded in red argillaceous marl, between two large strata of sandstone: the upper, solid, hard, and fine-grained; the under, loose, friable, and coarse. The stratum varies considerably in thickness; and in some places, immediately below it, there is a thin bed of a soft umber-like substance, which, on examination, appears to be decayed wood. The lead-mines of Aldston-Moor contain a great variety of fluors, compact, foliated, amorphous, and crystallized. The colours are red, green, blue, yellow, purple, violet; and of all gradations, from very pale to almost black. They are sometimes found studded with brilliant quartz crystals, and with crystallized galena. In the magnesian genus is mica, which is found of many different colours, interspersed and incorporated with several kinds of stones, and particularly in most of the sandstone rocks. Spangles of silvery mica are met with in a red, slaty, friable stone, near the river Caldew, in the quarries on the Peteril, and various other places. The steatites, semi-indurated, white, streaked with pale green, has been found at Hill-Top and St. John's; and some of the solid white kind in Langnor iron-mine, at Borrowdale, and at one or two other places. Some small rounded masses of serpentine are met with in many parts on the sea-shore, and sometimes, but rarely, in ploughed grounds. Asbestos has been discovered in the lead mine at Northend, and in some of the mountains, where it presents a great variety of appearance, as it seems to graduate into different substances.

Of the silicious genus are quartz crystals, which are found in the mines of Aldston-Moor, beautifully transparent, and of various forms and colours: some of the yellow kind are but little inferior in brilliancy to the Brazilian topaz. Garnets are not unfrequently found in micaceous stones; and some beautiful small ones have been met with in the neighbourhood of Kefwick. Cornelians of various tints, but principally of different shades of red, are often discovered on the sea-shore, and near the surface of the earth in many other places. Jaspers of different colours, often veined, clouded, and spotted, are generally met with in beds of rivers, and on or near the surface of the ground. Many substances of the argillaceous genus are found in different parts of the county. Trap, whinstone, and toadstone, exist almost every where; the two latter generally in detached pieces on the surface. Schistus, of several varieties of colour, is found in immense strata in many parts; and schistose clay, frequently of a tabulated structure, resembling the leaves of a book, is met with in most coal-mines, at Gisland, Kefwick, and various other places. Terra-porcellanea, or porcelain clay, the kaolin of the Chinese, is found at Barrock, near Nestleps: it is of a white and cream colour, mostly friable, and dusty; it contains minute particles of shining silvery mica. On the banks of Ullswater, tripoli is frequently discovered in rounded lumps, of a greenish colour, in gravel beds sometimes, and in coarse martial clays. Fossil, or pit-coal, is found in many parts of the county, and of very different qualities. It is met with at various places along the eastern mountains; but is easiest of access, and in the greatest abundance, on Talkin and Tindale Fells, whence Carlisle, Penrith, and

Brampton are chiefly supplied. On the west side of the river Caldew, near Calbeck, and thence to Maryport, Workington, and Whitehaven, it exists in great abundance; and many coal-mines are constantly at work in this district, and particularly at Whitehaven. Some very large pits have also been opened at Workington and Tindale Fell, near Brampton. Thin layers of jet are sometimes found in the rocks on the Irthing, in small detached pieces in the bed of that river, on the sea-shore, and near the surface of the earth in other places. Wallerius, and other eminent chemists, have supposed it to be asphaltum, condensed and hardened by length of time. It bears a fine polish; and is frequently worked into toys, bracelets, boxes, buttons, and other articles. The famous black-lead, or wadd mines, are situated at the head of Borrowdale, in a place extremely difficult of access, and, for the riches and qualities of the substance, are unequalled by any in the world. The mines lie to the east of a very steep mountain, which forms the west side of the vale of Stomathwaite. There are two workings: the lower one is about 340 yards above the level of the sea, and its perpendicular depth about 105 yards; the upper one is nearly 390 yards above the sea, and its depth about 30. The strata of the mountain are very irregular, and broken; and the black-lead appears to have been formed in the fissures. The mineral itself does not exist in regular strata, but is found in irregular masses. It is described as lying in the mine in form resembling a tree, having a body or root, and veins or branches spreading from it in different directions: the root or body is the finest black-lead, and the branches the worst; growing proportionally more inferior, as they become distant from the parent stem. The veins, or branches, sometimes shoot out to the surface of the ground; yet these indications are very rare. The black-lead is generally embedded in a blue rock, which is not unfrequently stained as black as the mineral itself to the depth of two or three feet; sometimes there is a wet sludge between the rock and the black-lead; at others it is found in lops, or lumps, in a body without branches. In the deepest mine, the black-lead lies in two veins, crossing each other; the main body, and richest in quality, being at the point of intersection: these veins fall perpendicularly to the depth of 40 fathoms. The blue stone, where the black-lead is commonly found, has often a stratum of hard granite above it. Quartz crystals are frequently discovered in the working. The country in the immediate vicinity of the wadd mines has been described by a native of Cumberland (Mr. George Smith), as full of cataracts and rivers, that are precipitated from the crags with an alarming noise; and the summit of the mountain itself, in whose bowels this valuable mineral is produced, has been depicted by the same gentleman as truly terrifying. "Not a herb was to be seen but wild savine, growing in the interstices of the naked rocks; while the horrid projection of vast promontories, the vicinity of the clouds, the thunder of the explosions in the slate quarries, the distance of the plain below, and the mountains heaped on mountains that were piled around us, desolate and waste, like the ruins of a world which we had survived, excited such ideas of horror as are not to be expressed." The value of this substance, and the singular fraud of an owner of a contiguous part of the mountain, who secretly sunk a shaft, and opened a passage diagonally to the mine, occasioned an act of parliament to be made in the reign of George II. to prevent its being stolen, by subjecting the criminal to the same punishment as for felony. In this act there is a recital, that black-lead hath been discovered in one mountain or ridge of hills only in this kingdom; and that "it hath been found, by experience, to be necessary in the caking of

bomb-shells, round-shot, and cannon-balls." The chief use to which it is now applied is drawing; and the lead of some pencils made at Kewick is of so very fine a texture, that it bears a point nearly as sharp as that of a needle. Some assert that it may be used medicinally, to ease the pains of the gravel, stone, strangury, and colic.

The principal metallic substances of Cumberland are lead, copper, and iron ores. The lead mines are chiefly in Aldston-Moor, on the south-east borders of the county, where about 1100 men are employed, and clear to the owners upwards of 10,000*l.* *per annum*. In working some of these mines, the miners frequently meet with large breaks in the rock, like grottoes, wholly encrusted with the most beautiful spar, which, on entering, has the richest appearance imaginable. The whole cavern, by the light of a candle, reflected from a thousand points, appears as if bespangled with gold, silver, and diamonds. These internal openings are generally closed up as soon as found; the spar they contain being a great temptation to the workmen to neglect the service of their employers, as they could obtain more by gathering and selling spar than by their own business. Galena is found, in all its varieties, in the mines in the vicinity of Aldston, Kewick, and Caldbeck; and it not unfrequently contains a considerable portion of silver. The lead ores, in the mines of Aldston-Moor, are found lying in cracks or fissures. These fissures, though commonly nearly perpendicular, are never wholly so; and in whatever direction they are found, they always incline downwards from that side where the strata are highest: thus, in a vein from north to south, if the strata should be raised higher on the south side the fissure than on the north side, its inclination will then be from the south downwards to the north. The copper ores are commonly combined with sulphur, and generally contain both iron and arsenic. The most considerable copper mines are near Caldbeck, at Hesketh New-Market in Borrowdale, and at Newlands in the neighbourhood of Kewick, where the celebrated mine of goldcarp is situated; from which, by the old workings, and written documents, it appears that immense quantities of copper have formerly been obtained. Specimens of copper ores have been found in the mountains named Hard-knot and Wrynose, and at some other places. Ochreous iron ores, resembling those called by Mr. Kirwan highland argillaceous ores, are very commonly met with either on or near the surface, in most parts of the county, especially in moory soils, and where the under-stratum is a coarse martial clay. They appear to have been deposited by water, as they are generally found concreted with small stones, roots, and other substances. In the parish of Egremont, at a place called Crowgarth, is the most singular mine of iron ore supposed to be in Great Britain. It lies in the earth, at the depth of 12 fathoms; and the thickness of the band of ore, which is hard solid metal, is between 24 and 25 feet. It was never known to be much wrought till the years 1784 and 1785, when it was more generally opened; and so great has been the demand for it, at Carron foundry in Scotland, and some other places, that, in 1791 and 1792, the annual exportation was 20,000 tons and upwards. At Langnor, between Whitehaven and Egremont, many varieties of the hæmatites are found, and sometimes, from their colour and shape, are called kidney ore. Native Prussian blue is sometimes found in the peat-moss of this county, and in clay, particularly that of Eterby-Scar, near Carlisle; its qualities, however, are different from the artificial.

Among the semi-metals, blende, pseudo-galena, or black-jack, is met with in the greatest plenty. Its forms and colours are very different: some is bluish, resembling galena;

black, or greenish-black, like pitch; of a glassy shining surface, often crystallized, in irregular pyramids, and other irregular figures; sometimes containing silver, arsenic, and other substances. Oxyd of zinc has been found at Borrowdale and Ousley. A mine of cobalt was discovered about ten years since, in the parish of Croftwaite, near Cowdale, about four miles from Keswick; but has hitherto been little regarded. Antimony has been found at Bassenthwaite; and in the stratum under the coal at Tindale Fell, oxyd of manganese, tinged and intermixed with pyrites and mica: it has also been discovered at Caldbeck.

This county abounds with lakes, some of which will be hereafter described under LAKE. The principal are known by the names of Ulls-water, which occupies an area of about 9 miles in its greatest length, by about three-quarters of a mile, on an average breadth; Thirlmere, or Leathes-water, a narrow irregular sheet of water, about 3 miles in length, skirts the immense base of Helvellyn; Derwent-water, or Keswick lake, is rather of an oval figure, and extends nearly 3 miles in length, and about half so much in breadth; Bassenthwaite-water, or Broad-water, which is nearly 3 miles north of Keswick lake, abounds with beautiful scenery, and is 4 miles long, and 1 in its greatest breadth; Over-water, in a barren situation between Binsley and Caldbeck-fells, is about half a mile in length, and in breadth somewhat more than a quarter of a mile; Lowes-water, beautifully situated near the north-western extremity of the mountains above Mellbreak, is about a mile long, and a quarter broad, and, contrary to all the others, discharges its waters at the southern end; Crummock-water expands its pellucid bosom beneath some lofty mountains, and extends nearly 4 miles in length, and half a mile in breadth; Buttermere-water, about a mile south of Crummock-water, from which it is separated by a luxuriant vale, is about a mile and half long,

and half a mile broad, into which numerous torrents pour down from the mountains, one of the roaring cataracts falling between four and five hundred yards; Ennerdale-water spreads among the mountains near to Whitehaven, and guarded, on every side but the west, with craggy and almost impassable heights, possesses a space of about 2 miles and half in length, its greatest breadth being about three quarters of a mile; Wast-water expands its crystal surface in the bosom of Wastdale, to the length of 3 miles, and breadth, in the widest part, of three quarters of a mile; Burn moor-tarn, seated among the wildest mountains at the head of Miterdale, covers about 250 acres; Devoek-water occupies about 300 acres, amongst the hills south-east of Ravenglass; Talkin-tarn and Tindale-tarn possess about 40 or 50 acres each, on the moors south-east of Brampton; and Turn-wadling spreads its waters over 100 acres, on a barren common, 1 mile west from the river Eden, at Armathwaite.

The mountains of Cumberland are exceedingly numerous, and many of them of immense elevation, and singular structure. They enter into the composition of almost every view; and either by their sublime heights, their romantic forms, the dignified grandeur of their aspects, the immensity of the rocky masses that compose them, or the wild, awful, and imposing majesty of their appearance, are well calculated to give birth to interesting emotions.

The rivers and smaller streams of this county are very numerous. The principal are the Eden, the Eamont, the Uddon, the Ehen, the Derwent, the Greata, the Cocker, the Ellen, the Waver, the Wampool, the Caldew, the Peteril, the Esk, the Liddal, the Line or Leven, the Irthing, and the Gelt. Hutchinson's History of the County of Cumberland, 2 vols. 4to. Housman's Topographical Description of Cumberland, &c. 8vo.

Cupel

CUPEL, or **CUPELLATION**, in *Chemistry*. Cupellation is a process employed in the assay of gold and silver, by which the alloy, or base metal, with which any sample of the noble metals may be mixed, is separated, and its proportion ascertained. The rationale of this process is founded on the following facts.

Of all the metals hitherto discovered, three alone (namely, gold, silver, and platina,) are incapable of being oxydated or rusted by mere exposure to air, either when solid or in fusion; and hence gold and silver anciently acquired the name of *noble* metals. All other metals tarnish and are oxydated when kept in fusion in open vessels, (some with extreme ease, others not without difficulty,) so that by constantly removing the skin of oxyd as it forms, and exposing fresh surfaces to the air, the whole metal may be finally changed into oxyd. Hence when a mixture of a *noble* and a *base* metal (or in other words, of a metal unchanged, and of one oxydable by fusion,) are melted and exposed to air, the base metal gradually changes to an oxyd, and is thrown off in the form of coloured scales or glassy pellicles, and the noble metal remains unaltered. This separation, however, is not in all cases equally accurate, for where the *alloy* or base metal is not very easily oxydable, and where the proportion of the alloy to the noble metal is but small, the affinity which the latter exercises towards the former is so great, and increases so much with the decreasing proportion of the alloy, as to protect it completely from any further action of the air, and to preserve it in the metallic state. Thus, for example, if a mixture of equal parts of silver and copper are kept in fusion in an open vessel, a crust of brown oxyd of copper readily forms, which, if removed, is succeeded by other crusts that continue to be produced, but with increasing difficulty, till the copper is only about a twelfth of the mass; but after this point scarcely any continuance of heat will complete the oxydation of the remaining portion of the alloy.

The same, however, does not take with lead when alloyed with silver, for on fusing the mixed mass the lead speedily oxydates on the surface, and at the same time vitrifies into litharge, and if this is removed, every particle of lead may be thus extracted, and the silver alone left behind perfectly pure.

Now it is found that when a triple alloy of silver, copper, and lead, is mixed together (the quantity of lead being

several times greater than that of the copper) the oxydability of the copper is so much increased by the presence of the lead, owing to the affinity of the two oxyds, and the solubility of the copper oxyd in that of the lead when in fusion, that the silver is no longer able to protect any portion of the copper from oxydation, and the whole alloy is removed from the noble metal, even to the last sensible particle.

This, therefore, is the principle on which the process of cupellation is founded, namely, that of mixing the alloyed noble metal with a considerable portion of lead, exposing the whole to a melting heat with access of air, and thus converting to an oxyd both the lead and every other base metal present in the mass, till the noble metal is left behind perfectly pure.

This process is performed both in the large way in extracting silver from the ore and refining it, and in the small way in assaying those mixtures of gold and silver with different alloys which are used in such large quantities for plate, coin, &c. &c. The former, indeed, is technically called refining, and the latter only cupellation, and some little variation in the management of each takes place, but the principle in both is precisely the same.

Cupellation is usually performed in a furnace contrived for the purpose, and capable of giving a pretty intense heat. The body of the furnace is a hollow four-sided prism, in the middle of which is fixed an earthen vessel called a muffle, of an oven shape, vaulted at top, entirely open at one end, and with a flat floor at bottom. The open end of the muffle comes in close contact with a corresponding hole in the side of the furnace, and is luted to it, and the closed end projects as far as the centre of the furnace. By this contrivance the muffle is heated by the fuel round it, whilst not a particle of the burning charcoal can fall into its cavity, and a gradation of heat is also obtained within it, being the most intense at the closed end which is in the centre of the fire, and the least at the open end contiguous with the hole in the side of the furnace. The cavity of the muffle being large in comparison with the vessels which it is to contain, a considerable body of heated air is constantly circulating over the melted metal, which is necessary to keep up the constant oxydation of the lead and alloy on which the process of cupellation depends.

But as it would be nearly impracticable to keep up the

requisite heat within the muffle, whilst one side was entirely open to the external air, a small vestibule or shelf of iron is made to project a few inches from this opening, on which several long cylinders of charcoal are heaped up whilst the process is going on, which take fire by touching the end of the red-hot muffle, and partially block up the opening, so as fully to heat the outer air in passing to it.

The melted metal is contained in small earthen vessels called *cupels*, which are small solid cubes or cylinders about an inch or an inch and a half across, and with a small depression at top which lodges the melted globule. The cupels may be made of any earth of little cohesion, such as the ashes left after the lixiviation of the saline residue of burnt wood, which are much used in *refining*; but for *cupellation*, or assaying in the small quantities, the cupels are made entirely of bone-ash or phosphat of lime, which possesses the qualities of porosity and infusibility in an eminent degree. This is ground to a fine powder, then a little moistened with water, and the mass (which possesses scarcely any cohesion) is forcibly struck into an iron or a brass mould, where it takes the requisite form, and on drying becomes solid enough for use. The cupels are so small that several of them may be ranged side by side on the floor of the muffle; and they are so extremely porous that the fused oxyd of lead sinks into their substance with as much ease as water into a lump of chalk, but all of the globule of metal that remains in the metallic state is detained in the little cavity on their surface. It should be observed, that the cupels cannot absorb more than their own weight of litharge at the utmost, so that the quantity of metal used and the required proportion of lead must be regulated accordingly.

Experience has shewn the extreme accuracy and nicety of manipulation requisite to conduct cupellation with uniform exactness, and yet there is no process in which accuracy is of more real importance, since the quantities operated on are at most only a few grains, which are taken as samples of the purity and consequent value of very large masses of gold and silver. Hence, too, scales and weights of uncommon delicacy are required.

Cupellation of Silver.

For the assay of silver a clean piece of the metal is taken, which is not more than 36 grains, and less if the alloy appears abundant, is laminated, and weighed with the utmost care. It is then wrapped up in a piece of sheet-lead of the proper weight, or both the silver and lead are folded in paper ready for use. The purity of the lead is important; for all lead naturally contains a little silver, which, if not removed, might make a sensible error in the assay. The lead is, therefore, always revived from litharge; in which state it is remarkably pure, and contains no more than $\frac{1}{2}$ grain of silver in the pound, which quantity may be entirely neglected.

The mode of proportioning the quantity of lead to the estimated quantity of alloy in the silver will be presently noticed.

The fire being kindled, and the floor of the muffle sprinkled with chalk, to prevent the cupels from being glued to it in the process, the muffle and empty cupels are first made fully red-hot, and the cylinders of charcoal are put against the open end of the muffle, as already described. The silver and lead are then dropped into the cupel, and the charcoal replaced. The metals immediately melt together; and, when red-hot, the following appearances take place. The melted globule begins to send off dense fumes, which rise to the roof of the muffle, and at the same time

a thin stream of red fused matter is seen constantly flowing down the sides of the globule to the surface of the cupel, through which it sinks. This fume is the oxyd of lead evaporated by the heat, and the stream of fused matter is the melted litharge, together with the copper or other alloy of the silver which is thus extracted from it. In proportion to the intensity of the heat are the density of the fume, the violence with which it is given off, and the rapidity with which the melted oxyd *circulates*, as it is termed, or falls down the sides of the metal. As the cupellation advances, the melted globule becomes rounder, and its surface more streaky, till, in about fifteen or twenty minutes, according to circumstances, all the lead and alloy are vitrified and absorbed by the cupel, the last portions of litharge collect in large bright streaks, which disappear with great rapidity, shewing the melted metal beneath bright with iridescent colours, which suddenly after becomes opaque, and exquisitely white and brilliant, exhibiting the clean surface of pure melted silver. This last appearance is called the *lightning* of the metal, and it is highly beautiful, as if a red curtain was suddenly withdrawn from the metal. The operation is now finished, and the cupel is drawn forwards to the open side of the muffle, that it may cool gradually before it is removed; for, if it were suddenly fixed, the globule is apt to shoot into an arboresecent surface in the act of congealing, by which small particles are thrown out of the cupel and lost, and the assay is spoiled.

In the cupellations made at the mint assay-office, two assays are made of the same metal, and no sensible difference between the weight of the two buttons is allowed to pass, as ascertained by scales, that turn with the $\frac{1}{128000}$ th of a grain.

The process is considered as well performed when the button of silver adheres but slightly to the cupel; when its shape is very considerably globular, and not flattened at the margin; when it is quite white, clean and brilliant, and not fouled or spotted with any remaining litharge. In this state of purity, the surface of the button is never quite smooth, but is somewhat scaly or striated, the effect of a very strong tendency to crystallization, which perfectly pure silver possesses, but is not found in plate or alloyed metal. Under the microscope, this irregularity of surface is still more observable, and the scales seem to incline to a pentagonal form.

Where the alloy of the silver is only copper, as is usually the case, the cupel round the button is stained of a brown grey.

The management of the fire in cupellation is of great importance. If it is so intense that the cupel can scarcely be distinguished from the muffle, and the fume of litharge can hardly be discerned through the dazzling heat, not only much of the lead is volatilized to mere waste, but even a portion of the silver is carried off along with it, which renders the assay inaccurate. Even silver alone, and in the greatest purity, may be evaporated by intense heat as M. Tillet (an ingenious French chemist, and master of the mint at Paris) found, by an experiment, in which a button of pure silver was intensely heated for two hours, and had lost thereby no less than $\frac{1}{80}$ of its weight. If one vessel is inverted over another that contains the silver, in this case the inside of the upper one is found studded with minute globules of silver, when viewed through a common lens. On the other hand, when the fire is too slack in cupellation, the litharge is not fully melted as it forms, and, therefore, is not absorbed by the cupel, but lies on the surface as a red scoria, and the circulation is very sluggish. The proper medium of heat is, when every thing within the muffle is fully red-hot; when

the fume of litharge is abundant, and visibly rises to the top ; and when the circulation goes on rapidly, and the button continues very globular. Towards the end of the process, the heat should be increased as the button, by the constant abstraction of the lead, becomes constantly less easily fusible.

It has been already mentioned, that in cupellation all the alloy of the silver is carried down into the cupel along with, and dissolved in the litharge, provided lead enough be used. But it was also found by M. Tillet, that a small portion of the silver is at the same time carried down with the lead ; so that, when perfectly pure silver is cupelled with lead of known purity, the button of silver left after the process never weighs quite so much as before, even though the heat employed is so moderate as not to volatilize any of the silver. As a proof that some of the silver is carried down into the cupel, M. Tillet ground this vessel to powder, and fused it with a reducing flux, whereby he recovered nearly all the lead that had been used, and which now contained ten times as much silver as its natural retent of this noble metal, nine tenths of which, therefore, must have been derived from the button of silver during cupellation. Accordingly, on cupelling this lead, *per se*, it left behind all this excess of silver, and now only carried down its natural retent, which amounts to about $\frac{1}{11\frac{1}{2}}$, or half a grain in a pound French.

It remains to give the proportions of lead to alloy, which have been found the most useful in cupellation, and the method of estimating the quantity of alloy previous to this operation, with sufficient exactness to guide the artist. The ancient assayers used for this purpose small slips or bars of metal, made with pure silver and copper, in known proportions, in a regularly increasing series, from the least to the greatest quantity of alloy usually required. These sets of bars were called *touch-needles* ; and, by comparing the silver to be assayed with these needles, in colour, tenacity, and other external marks, its proportion of alloy was guessed at with sufficient accuracy to determine the quantity of lead required in the cupellation. These needles are now, however, almost totally diffused in silver-assaying, as an experienced assayer is able to judge of the fineness of silver, with quite sufficient accuracy, by the ease with which it is cut, the colour and grain of the fresh-cut surface, the malleability, the appearances on being heated red-hot, and other tokens.

The proportion of alloy (if copper) to the silver being found with sufficient exactness, that of the lead is thus estimated. Copper, when taken by itself, requires from 10 to 14 times its weight of lead for complete scorification on the cupel. But all admixtures of fine metal tend to protect the copper from the action of the litharge, the more, in proportion to the quantity of fine metal. Thus, when one part of copper is mixed with three of silver, no less than 40 parts of lead are required ; and one part of copper with 11 of silver require 72 parts of lead. It should be observed, however, that a considerable difference in the respective proportions of lead to copper is observed by different assayers, though the general principle of increasing the lead in proportion to the quantity of fine metal is indisputable.

The following table will shew some of the proportions used in the French mint, as given by M. Tillet, and also others used by the German chemists, as given by Gren :

per.		Silver.		Lead.
1	with	0	requires	10.
1	—	$\frac{1}{15}$	—	17 Ger.
1	—	$\frac{1}{11}$	—	28 Fr.
1	—	$\frac{1}{8}$	—	20 Ger.
1	—	$\frac{1}{5}$	—	29 Fr.

Copper.		Silver.		Lead.
	with	$\frac{1}{2}$	requires	30 Fr.
	—	1	—	32 Fr.
	—	2	—	36 Fr.
	—	3	—	40 Fr. and Ger.
	—	4	—	56 Ger.
	—	5	—	48 Fr.
	—	7	—	64 Ger.
	—	11	—	72 Fr.
	—	15	—	96 Ger.
1	—	23	—	96 Fr.
1	—	30	—	128 Ger.

Cupellation of Gold.

The process of cupellation is the same for gold as for silver, the alloy, in both instances, being worked off by lead ; but several curious circumstances take place with mixtures of gold with other metals, which are not easily explicable. When pure gold is mixed with lead and cupelled, the whole of the lead is not separated, as it is with pure silver, but a small portion remains combined with the gold sufficient to impair its colour and ductility. If, besides gold and lead, the mixture contains copper to the amount of $\frac{1}{4}$ of the gold, the whole of the lead will now be separated in cupellation, but almost the whole of the copper will remain. If, in addition to the above ingredients, the alloy contains a somewhat greater proportion of silver than it does of copper, this latter is separated by cupellation, but a little of the lead remains. But if the amount of silver equals or exceeds that of the gold, all the lead and copper are separated, and only the gold and silver remain.

As, therefore, the object of cupellation is to separate the whole of the alloy of base metal, it is necessary, in assaying gold, to add first a very considerable quantity of silver, then to work off the copper, and other base metal, by lead on the cupel, and afterwards to separate the gold and silver by the process of *parting*, as it is called, by means of nitric acid.

The assay of gold, therefore, is more complicated than that of silver, and requires the intervention of this latter metal. The quantity of silver must, as already mentioned, be at least equal to that of the gold, to enable the lead to extract all the copper in cupellation ; but, in fact, the silver is generally three times as much as the gold, otherwise, though all the copper may be removed by a much less proportion, the subsequent separation of the silver from the gold by nitric acid cannot well take place. For it is found that, unless the silver be in this large quantity, the gold, which is not itself touched by the nitric acid, also protects a portion of the silver from the acid, and the separation is not complete.

The cupellation of gold therefore is conducted in the following manner : the quantity of copper or other alloy present, being first estimated as accurately as possible in the way that will be presently mentioned, as much fine silver is added to the mixture, as will make the gold only a *fourth* of the mass when the base alloy has been removed. If the gold is already alloyed with any silver, a proper allowance is of course made for the estimated quantity. This proportioning of the silver to the gold, and melting them together, is called *quartation*, the gold being reduced thereby to one-fourth of the mass of noble metal. To the mixture the requisite quantity of lead is then added (which is nearly the same as in silver assaying) and the cupellation is conducted exactly in the same manner, only that a higher heat may be given, as the silver in this mixture is not volatilized by a strong fire, as it is in mere silver assaying. The *lighting*

takes place here also when every particle of lead and other base metal is removed, and only the gold and silver are left on the cupel.

The separation of these noble metals by nitric acid, and the exact process of parting, will be described under GOLD. It may be just mentioned, however, that the button is first flattened, and then rolled out into a small coil, and then put into a glass, and with boiling nitric acid, by which all the silver is extracted, and the gold alone is left behind in perfect purity.

The quantity of alloy in any mixture of gold with other metals is estimated previous to cupellation, partly by the general appearance (the nature of the alloy being known) and partly by the use of the touch-stone. In judging by the general appearance alone much advantage may be derived from touch-needles, but the case is more complicated here than in silver assaying, since three metals at least are concerned in gold assaying, namely, gold, silver, and copper. Therefore if these needles are used, there must be several sets of them adapted to the nature of the alloy.

The trial by the touchstone is another simple and very ingenious method of forming some estimate of the proportion of alloy in any gold mixture. For this purpose the piece of metal to be tried is rubbed hard upon a piece of black basalt or black pottery, so as to make a broad bright metallic streak by the abrasion of some of the metal. This shews at once the true colour of the alloy, which may also be compared with another streak made by a touch-needle beside it. A drop or two of nitric acid is then spread upon the streak, and after remaining about ten seconds, it is washed off, and the effect observed. If the streak preserves its golden colour unaltered, the metal is judged to have a certain degree of fineness, as gold is insoluble in this acid; if it looks red, dull, and coppery, it is less fine; if the streak is almost entirely effaced, the metal contains very little gold; and thus by the assistance of this acid, an experienced assayer will come at a sufficiently accurate knowledge of the quantity of alloy to guide him in the addition of lead and silver in the cupellation. It is found however that though pure nitric acid will readily dissolve copper singly, it will not act sensibly on this metal, when in mixture with twice its weight of gold, so effectually does the gold protect the copper against this powerful acid. But if a small proportion of muriatic acid is added, the copper will be dissolved when the gold is not more than three-fourths of the mixture, and thus the power of this test is much extended. Vauquelin, in his "*Manuel de l'Essayer*," recommends for this purpose an acid composed

of 98 parts of nitric acid of 1.34 sp. g., 2 parts of muriatic acid of 1.173 sp. gr., and 25 parts of water. This does indeed compose a nitro-muriatic acid, which is the proper solvent for gold, but the gold on the touch-stone is not in this case sensibly acted on, owing to the shortness of the application, and the very small proportion of muriatic acid.

Touching is also of great use in determining the value of wrought trinkets which cannot spare so much as 8 or 10 grains for a regular assay.

Cupellation of Alloys of Platina.

On account of the great specific gravity of platina, it was long apprehended that gold might be adulterated with it to a considerable degree without being easily detected, for as platina is equally unoxidable by air as gold and silver, it cannot be scorified by lead on cupel, and being insoluble in nitric acid its separation from gold is not readily effected. It is not difficult, however, to detect this metal when mixed with gold or silver even in very small proportion.

Gold alloyed with so little as one *per cent.* of platina and cupelled in the usual way, with thrice its weight of silver, differs from gold and silver alone in requiring a much greater heat for cupellation and complete fusion of the button; otherwise, when all the lead is worked off, the button remains flat, like a piece of money, and its surface knotty. Even when the button is well fused its edges are much thicker, and rounder than in common gold assays, its colour duller, and especially it appears remarkably crystallized on its surface. Also in cupellation, when the last portions of lead are worked off, the button appears puffy, scarcely iridescent, and does not lighten, or become suddenly brilliant as silver and gold alone, or gold and silver do.

Silver bears alloying with platina better than gold does; but this is never done fraudulently. When the platina does not exceed 5 *per cent.* of the silver, it works easily on the cupel, but the *lightning* is less observable than with pure silver, and, in particular, the property of crystallizing is still more conspicuous. When the platina amounts to a quarter of the mixture, the button or cupel flattens, and becomes puffy even before all the lead is run off, and its surface shoots up into knobs which, when seen by a magnifier, appear clusters of crystalline points.

Some remarkable occurrences take place with the alloys of gold or silver with platina, when treated with nitric acid, which will be mentioned under that metal.

Currying

CURRYING is the art of dressing cow-hides, calve-skins, seal-skins, &c. principally for shoes ; and this is done either upon the flesh or the grain.

In dressing leather for shoes on the flesh, the first operation is soaking the leather in water, until it be thoroughly wet; then the flesh-side is shaved on a beam, about seven or eight inches broad, with a knife of a peculiar construction, to a proper substance, according to the custom of the country, and the uses to which it is to be applied. This is one of the most curious and laborious operations in the whole mystery of currying. The knife used for this purpose is of a rectangular form, with two handles, one at each end, and a double edge. They are manufactured at Cirencester, and composed of iron and steel; the edge is given to them by rubbing them on a flat stone of a sharp gritty substance, till it comes to a kind of wire; this wire is taken off by a fine stone; and the edge is then turned to a kind of groove wire by a piece of steel, in form of a bodkin, which steel is used to renew the edge in the operation.

After the leather is properly shaved, it is thrown into the water again, and scoured upon a board or stone commonly appropriated to that use. Scouring is performed by rubbing the grain or hair-side with a piece of pumice-stone, or with some other stone of a good grit, not unlike in thickness and shape to the slate with which some houses are covered. These stones force out of the leather a white sort of substance called the bloom, produced by the oak-bark in tanning. The hide or skin is then conveyed to the shade or drying-place where the oily substances are applied, termed stuffing or dubbing; the oil used for this purpose is prepared by the oil leather-dressers, by boiling sheep-skins or doe-skins in cod-oil. This is put on both sides of the leather, but in a greater and thicker quantity on the flesh than on the grain or hair-side.

Thus we have pursued the currying of leather in its wet state, and through its first stage, commonly called getting out.

When it is thoroughly dry, an instrument with teeth on the under-side, called a graining board, is first applied to the flesh-side, which is termed graining; then to the grain-side, called bruising; the whole of this operation is intended to soften the piece of leather to which it is applied. Whit-

ening or paring succeeds, which is performed with a fine edge of the knife already described, and used in taking off the grease from the flesh. It is then boarded up or grained again, by applying the graining board, first to the grain and then to the flesh.

It is now fit for waxing, which begins with colouring. This is performed by rubbing with a brush dipped in a composition of oil and lamp-black on the flesh, till it be thoroughly black; it is then sized, called black sizing, with a brush or sponge, dried, tallowed with a woollen cloth; and slicked upon the flesh with a broad smooth piece of glass, sized again with a sponge; and when dry this sort of leather, called waxed or black on the flesh, is curried.

Currying leather on the hair or grain-side, termed black on the grain, is the same in the first operation with that dress on the flesh, till it is scoured. Then the first black is applied to it, while wet; which black is a solution of copperas in fair water, or in the water in which the skins, as they come from the tanner, have been soaked; this is first put upon the grain, after it has been rubbed with a stone; then rubbed over with a brush dipped in stale urine; slicked out with an iron slicker, in order to make the grain come out as fine as possible; and then stuffed, in the manner already described among the first operations of currying; and when dry it is seasoned, *i. e.* rubbed over with a brush dipped in copperas water on the grain, till it be perfectly black; then slicked with a stone of a good grit, to take out the wrinkles and coarse grain as much as possible: after this the grain is raised with a fine graining board, by turning the skin or piece of leather in various directions; and when a little dried, it is bruised in order to soften it. When it is thoroughly dry it is whitened, bruised again, and grained in two or three different ways; and when oiled upon the grain with a mixture of oil and tallow, it is finished.

Bull and cow-hides are sometimes curried for the use of saddlers and collar-makers; but the principal operations are much the same as those we have already described. It should, however, be observed, that only a small portion of flesh is taken from hides designed for these purposes. Hides for the roofs of coaches, &c. are shaved nearly as thin as shoe-hides, and blacked on the grain.

Cutlery

CUTLERY. Under this head we shall comprise the articles knives, forks, razors, and scissors. They are all either made of steel or of iron, with steel to form the edge.

Three kinds of steel are made use of in the manufacture of different articles of cutlery, *viz.* common steel, shear-steel, and cast-steel; these different kinds are made from what is termed blistered steel, which has hitherto been obtained of good quality only from certain kinds of bar iron brought from Sweden and Russia.

The bar iron is stratified with powdered charcoal in a furnace termed a converting furnace, within a recess termed a pot, from 7 to 14 feet long, 3 feet broad, and 2½ feet deep, the whole covered close up with a mixture of clay and sand, so as to prevent the access of atmospheric air. A strong heat is applied for about 8 days; as soon as the pot is cooled, which is in about 8 days more, the bars are taken out, and the iron is found to be converted into steel; it always appears blistered upon the surface, and hence is termed blistered steel. When these bars are taken to the tilt, and drawn into rods of various dimensions, it is called common steel. All the cheaper cutlery are made of this steel, and also all kinds of forks.

When a number of bars of blistered steel are laid together, heated to a welding heat in a forge furnace, and drawn down into bars under a forge hammer, they constitute what is termed shear steel. It has received this name from its being made use of to make wool shears. It is also termed Newcastle steel, from having been first made at that place.

Shear steel is exceedingly kind and tough. All the edge tools which require great tenacity without great hardness, are made of it, such as table-knives, scythes, plane-irons, &c. It is also freer from flaws, on account of the welding heat which has been given to it.

Cast-steel is formed by melting blistered steel in covered crucibles, and pouring it into cast-iron moulds, so as to form it into ingots: these ingots are then taken to the tilt and drawn into rods of suitable dimensions. No other than cast-steel can assume a fine polish, and hence all the finer articles of cutlery are made of it, such as the finest scissors, pen-knives, razors, &c.

Formerly cast-steel could only be worked at a very low heat; it can now be made so soft as to be welded to iron with the greatest ease. Its use is consequently extended to making very superior kinds of chissels, plane-irons, &c.

Forging of Table Knives.

Two men are generally employed in the forging of table knives, one called the foreman or maker, and the other the striker.

The steel called common steel is employed in making the very common articles; but for the greatest part of table knives which require a surface free from flaws, shear-steel is generally preferred. That part of the knife termed the blade, is first rudely formed and cut off. It is next welded to a rod of iron about ½ inch square, in such a manner as to leave as little of the iron part of the blade exposed as

possible. A sufficient quantity of the iron now attached to the blade, is taken off from the rod to form the bolster, or shoulder and the tang.

In order to make the bolster of a given size, and to give it at the same time shape and neatness, it is introduced into a die, and a swage placed upon it; the swage has a few smart blows given it by the striker. This die and swage are by the workmen called prints.

After the tangs and bolster are finished, the blade is heated a second time, and the foreman gives it its proper anvil finish; this operation is termed smithing. The blade is now heated red-hot and plunged perpendicularly into cold water. By this means it becomes hardened. Being thus hardened, it requires to be tempered regularly down to a blue colour: in this state it is ready for the grinder. Forks are generally a distinct branch of manufacture from that of knives, and are purchased of the fork makers by the manufacturers of table knives, in a state fit for receiving the handles.

The rods of steel from which the forks are made, are about $\frac{3}{4}$ ths of an inch square. The tang and shank of the fork are first roughly formed. The fork is then cut off, leaving at one end about 1 inch of the square part of the steel. This part is afterwards drawn out flat to about the length of the prongs. The shank and tang are then heated, and a proper form given to them by means of a die and swage. The prongs are afterwards formed at one blow by means of the stamp; this machine is very similar to that used in driving piles, but it is worked by one man. It consists of a large anvil fixed in a block of stone nearly on a level with the ground. To this anvil are attached two rods of iron of considerable thickness fixed 12 inches asunder, perpendicularly to the anvil, and diagonally to each other. These are fastened to the ceiling. The hammer or stamp, about 100 lbs. in weight, having a groove on either side corresponding to the angles of the upright rods, is made to slide freely through its limited range, being conducted by its two iron supporters. A rope is attached to the hammer which goes over a pulley on the floor of the room above, and comes down to the person who works the stamp: two corresponding dies are attached, one to the hammer, and the other to the anvil. That part of the fork intended to form the prongs, is heated to a pretty white heat and placed in the lower die, and the hammer containing the other die, is made to fall upon it from an height of about 7 or 8 feet. This forms the prongs and the middle part of the fork, leaving a very thin substance of steel between each prong, which is afterwards cut out with an appropriate instrument called a sie-press. The forks are now annealed by surrounding a large mass of them with hot coals, so that the whole shall become red-hot. The fire is suffered gradually to die out, and the forks to cool without being disturbed. This process is intended to soften, and by that means to prepare them for filing. The inside of the prongs are then filed, after which they are bent into their proper form and hardened. When hardened, which is effected by heating them red-hot and plunging them into cold water, they are tempered by exposing them to the degree of heat at which grease inflames.

Penknives are generally forged by a single hand with the hammer and the anvil simply. The hammer in this trade is generally light, not exceeding $3\frac{1}{2}$ lbs. The breadth of the face, or the striking part, is about one inch, if broader it would not be convenient for striking so small an object. The principal anvil is about 5 inches, and 10 upon the face, and is provided with a groove into which a smaller anvil is wedged. The smaller anvil is about 2 inches square

upon the face. The blade of the knife is first drawn out at the end of the rod of steel, and as much more is cut off along with it as is thought necessary to form the joint. The blade is then taken in a pair of tongs, and heated a second time to finish the joint part, and at the same time to form a temporary tang for the purpose of driving into a small haft used by the grinder. Another heat is taken to give the blade a proper finish. The small recess called the nail hold, used in opening the knife, is made while it is still hot by means of a chissel, which is round on one side, and flat on the other.

Penknives are hardened by heating the blade red-hot and dipping them in water up to the shoulder. They are tempered by laying them side by side, with the back downwards upon a flat iron plate laid upon the fire where they are allowed to remain till they are of a brown or purple colour.

The blades of pocket knives, and all that come under the denomination of spring knives, are made in the same way.

The forging of razors is performed by a foreman and striker as in making table knives.

They are generally made of cast-steel. The rods as they come from the tilt are about $\frac{1}{4}$ inch broad, and of a thickness sufficient for the back of the razor.

There is nothing peculiar in the tools made use of in forging razors: the anvil is a little rounded at the sides which affords the opportunity of making the edge thinner, and saves an immense labour to the grinder.

Razors are hardened and tempered in a similar manner to penknives. They are however left harder, being only let down to yellow or brown colour.

The forging of scissors is wholly performed by the hammer, and all the sizes are made by a single hand. The anvil of the scissor-maker weighs about $1\frac{1}{2}$ cwt.; it measures on the face about 4 by 11 inches. It is provided with two gates or grooves for the reception of various little indented tools termed by the workmen bosses; one of these bosses is employed to give proper figure to the shank of the scissors; another for forming that part which has to make the joint; and a third is made use of for giving a proper figure to the upper side of the blade. There is also another anvil placed on the same block containing two or three tools called beak irons, each consisting of an upright stem about 6 inches high, at the top of which projects a horizontal beak; one of these beaks is conical, and is used for extending the bow of the scissors, the other is a segment of a cylinder with the round side upwards containing a recess for giving a proper shape and smoothness to the inside of the bow.

The shank of the scissors is first formed by means of one of the bosses, above described, leaving as much steel at the end as will form the blade. A hole is then punched about a $\frac{1}{4}$ inch in width a little above the shank. The blade is drawn out and finished, and the scissors separated from the rod a little above the hole. It is heated a third time, and the small hole above mentioned is extended upon the beak-irons so as to form the bow. This finishes the forging of scissors. They are promiscuously made in this way without any other guide than the eye, having no regard to their being in pairs. They are next annealed (for the purpose of filing such parts of them as cannot be ground) and afterwards paired.

The very large scissors are made partly of iron, the blades being of steel.

After the forging, the bow and joints, and such shanks as cannot be ground, are filed. The rivet hole is then bored, through which they are to be screwed or riveted together. The common kind of scissors are only hardened up to the joint. They are tempered down to a purple or blue colour. In this state they are taken to the grinder.

Grinding and polishing of Cutlery.

The various processes which come under this denomination are performed by machinery, moving in general by the power of the steam engine or a water wheel.

Grinding wheels or grinding mills are divided into a number of separate rooms; every room contains six places called troughs; each trough consists of a convenience for running a grindstone and a polisher at the same time, which is generally occupied by a man and a boy.

Two of the above troughs are represented in *Plate I. Cutlery*: A is a wooden wheel, called a drum, the axis of which runs through the whole length of the room. On the same axis are placed three other drums, one of the same length with the above, and two of half the length. Each of the large drums carries four straps, which give motion to the two stones *c, c*, and to the polishers *b* and *e*, by passing round their respective pullies *g, g, g, g*: *d, d, d, d* are the places where the workmen sit, and as he sits astride for the purpose of leaning over the stone, the seat is termed a horse.

The business of the grinder is generally divided into three stages, viz. grinding, glazing, and polishing.

The grinding is performed upon stones of various qualities and sizes, depending on the articles to be ground. Those exposing much flat surface, such as saws, fenders, &c. require stones of great diameter, while razors whose surface is concave, require to be ground upon stones of very small dimensions. Those articles which require a certain temper, which is the case with most cutting instruments, are mostly ground on a wet stone; for which purpose the stone hangs within the iron trough H, filled with water to such a height that its surface may just touch the face of the stone.

In the manufactories of Sheffield not less than five various qualities of stone are employed. The most valuable of the five is termed the Wickersley stone, from its being brought from a village of that name, about nine miles east of Sheffield.

It is of the sandstone kind, rather firmly indurated, of a compact texture. It appears to consist of very hard silicious particles cemented together with a softer medium. Both in the wet and dry state, it cuts with great facility, and is particularly adapted for grinding razors, penknives, table knives, and the inside of the blade of scissors.

Another very useful stone is termed the whitening stone. It is of a bluish white colour, exceeding the Wickersley stone in hardness, in firmness, and in closeness of texture. It is particularly employed for grinding the outside of the blade of scissors, and other articles requiring great smoothness and neatness of shape.

Forks, and the shanks of some scissors, are ground upon a dry stone, termed the fork-stone. It is a very sharp grit stone of a whitish colour, very similar to that of which mill-stones are formed. The stones employed for grinding saws and files are of a similar quality with the fork-stone, of a yellowish grey colour.

It is necessary that the stones move with a certain velocity, in order to produce a maximum of effect.

If the velocity be too great, two evils are generally to be expected: the first (which is most to be dreaded) is the breaking of the stone, the second is the stone almost ceasing to cut; this is also the case with drills, files, and other similar instruments; if they move too rapidly over the surface they are cutting, they generate much heat, but do not cut so well.

The surfaces of all stones are contrived to move with about the same velocity. This is effected by means of different sized pulleys. The drums above described are

four feet in diameter, and make from 120 to 140 revolutions in a minute, and the pulley on the axis of the stone must be of such diameter as to cause the surface of the stone to move at the rate of from 600 to 700 feet per second.

We cannot wonder at the dreadful effects of the breaking of a stone when we consider the great velocity with which they move. The horse or seat of the workman projects over the centre of the stone, and is secured to a beam of wood on a level with the ground by means of a strong chain. This in some measure secures the workman from those pieces of the stone, which might be projected upwards against the under side of the horse. But as it is quite uncertain what direction the fractured parts may take, the above contrivance is only a partial defence against these shocking accidents. It sometimes happens that the chain is broken, and the man and horse together projected to a considerable distance.

Means have been recently adopted by some of the grinders to prevent, in a great measure, the breaking of stones, which consist in a different method of fastening the stones upon the axis. The old method consists in wedging on the stone by means of wooden wedges. The improved method is to secure the stones to the axis by means of two circular plates, which are screwed firmly against the sides of the stone. By this means the parts of the stone are kept together. On the contrary, when the wedges are employed, a force is constantly exerted to break the stone; this effect is increased when the stones are used wet, from the circumstance of the wood absorbing moisture.

Glazing is a process following that of grinding: it consists in giving that degree of lustre and smoothness to an article which can be effected by means of emery of the various degrees of fineness. The tool on which the glazing is performed, is termed a glazer. It consists of a circular piece of wood, formed of a number of pieces in such a manner that its edge or face may always present the endway of the wood. Were it made otherwise the contraction of the parts would destroy its circular figure. It is fixed upon an iron axis similar to that of the stone: some glazers are covered on the face with leather, others with metal consisting of an alloy of lead and tin; the latter are termed caps. In others the wooden surface above is made use of. Some of the leather-faced glazers, such as are used for forks, table knives, edge tools, and all the coarser polished articles, are first coated with a solution of glue and then covered with emery. The surfaces of the others are prepared for use by first turning the face very true, then filling it with small notches by means of a sharp-ended hammer, and lastly filling up the interstices with a compound of tallow and emery.

The pulley of the glazer is so much less than that of the stone, that its velocity is more than double, being in general at the surface that of 1500 feet in a second. The glazer and its pulley are seen at *c* and *b*.

The process of polishing, consists in giving the most perfect polish to the different articles. Nothing is subjected to this operation but what is made of cast-steel, and has been previously hardened and tempered.

The polisher consists of a circular piece of wood covered with buff leather, the surface of which is covered from time to time, while in use, with the crocus of iron, called also co-leather of vitriol.

The polisher requires to run at a speed much short of that of the stone, or the glazer. Whatever may be its diameter, the surface must not move at a rate exceeding

70 or 80 feet in a second. This diminished velocity is effected by causing its stop to pass over the rounded part of the axis of the drum as shewn at B.

Grinding of Table Knives.

The stones made use of are from 35 to 45 inches in diameter, and about six inches broad upon the face. This stone is a species of sand stone, before termed the Wickersley stone. It is first turned, or raised exceedingly true, and then notched upon the face with a sharp-edged tool to make it cut faster. This species of stone cuts astonishingly fast, and has the peculiar property of not heating to a great degree any substance ground upon it. It is valuable on that account for grinding those articles which have been previously hardened. Table knives are ground first upon this stone, and afterwards upon one of finer texture, called the whitening stone. This prepares them for the glazing. The glazer is about 20 inches diameter and 5 inches broad, covered on the face with thick leather. This leather is thinly coated with glue, and is rolled in a quantity of emery. As soon as the glue is set the glazer is fit for use. It runs upon an iron axis, in the same manner as the stone. The bolster of the knife, when plane, is also ground and glazed in a similar way.

Forks.

The stone on which forks are ground are from 18 to 24 inches in diameter and about 2½ inches broad. It is a very sharp grit, something harder than that last mentioned. The face of the stone is a little rounded, for the purpose of meeting hollow parts, which are observed in all forks. The grinder holds the fork crosswise on the stone, and very dexterously gives it a kind of circular motion; by this means he makes the shank very round. The shank and neck of the prongs are ground upon this stone. The stone being dry, a profusion of sparks is given out, and the fork becomes heated with the great friction, till it is blue. The prongs are afterwards ground upon a wet stone, from 14 to 18 inches diameter and about 7 inches broad. The shank and neck of the prongs are finished upon a glazer of a similar shape to that of the stone on which they are ground; this glazer is of wood covered with leather, and prepared upon the surface with glue and emery, in the same manner as that for table knives. The prongs are finished upon a glazer of the same materials, but flat upon the face, about 8 inches both in diameter and breadth. The insides of the prongs are dressed by means of thin leather straps about 2 inches broad and 18 inches long; they are first coated with glue and then covered over with emery: as soon as the glue is set the strap is introduced between the prongs of the fork, and is drawn backwards and forwards till the part becomes sufficiently clean.

Grinding of Penknives.

The stone made use of for penknives is the Wickersley stone, about 16 or 18 inches in diameter when new, and is worn down to about 9 or 10 inches; the breadth is about 4½ or 5 inches. This stone, as has been before observed, having so little tendency to heat the substances ground upon it, is generally made use of dry for grinding penknives. There are several advantages in grinding upon the dry stone. It does not wear so fast. The edges of the stone are kept sharper and the surface even; but the great advantage is, that the stone cuts much faster. When the surface of a dry stone becomes clogged with the particles of steel adhering to it, a piece of soft iron is always at hand, which

being rubbed over it soon clears it of its incumbrance, and a fresh cutting surface is presented.

All the finer penknives, after being ground the first time, go back to be handled or hafted. The handles are wrapped in paper to keep them from being soiled, and the knives thus hafted are again returned to the grinder. The blades are all slightly ground over again upon a stone kept for the purpose of one determinate size. The flat parts of the blade are next glazed upon a glazer or lap made of lead, and for common articles of wood. After the lap is turned perfectly true, and a number of notches are made in the face; the surface is rubbed over with emery and grease. If it is found to cut too keen it is slightly rubbed over with bees wax. This process would finish the common sort of knives, but the finer blades are afterwards polished upon the polisher already described.

Grinding of Razors.

Razors are generally ground upon the stones which are laid aside by the grinders of penknives and scissiors. They take them when about the diameter of 8 inches, and wear them down to 4 or 5 inches. These small stones are highly proper for razors, in order to give to the blade a requisite degree of concavity and corresponding thinness to the edge. The razors are next glazed upon laps of metal, of a size corresponding with the size of the stone, and afterwards polished upon a polisher of wood covered with leather, similar to those used for penknives. The process of polishing, indeed, is always performed on the same kind of tool, differing only in size.

Grinding of Scissiors.

The stones made use of by the scissor-grinder are of two kinds; the one of the same size and quality with that used for penknives, and the other of the same nature with that used in the grinding of table-knives, and which the workmen term a whitening stone. The first is employed to grind the inside of the blades, and the latter for grinding the outside. Scissiors, the blades of which alone are hardened, are never sent to the grinder before they are hardened and tempered. After the blades of the scissiors are ground they are returned to the maker, and are fitted and screwed together, and properly adjusted for cutting. This being done, they are taken to pieces and returned to the grinder. The scissiors being slightly ground over again are finished upon their appropriate glazer. The insides of the blades, and all the other parts which are not rounded, are glazed upon a glazer of metal, of a size corresponding to the stone on which they were ground; for the inferior articles the glazer is of wood.

When the shanks of scissiors are sufficiently plane to admit of grinding, they are sent to the shank-grinder, a workman solely employed in grinding the shanks and in dressing those parts of the scissiors which have been filed, and which cannot be touched by the glazer.

The shanks of larger and commoner sorts of scissiors are ground upon a stone similar to that used for grinding the shanks of forks, but the finer kinds are ground upon the Wickersley stone already described. Being ground, they are glazed upon a glazer of wood faced with leather, of the same size and shape with the shank of the scissor. The remaining parts of the scissiors, which have been only filed and rubbed with sand but are still destitute of polish, are finished by brushing.

The brush is an instrument consisting of a circular piece of wood set upon the face with very hard bristles. Two brushes are generally employed in succession. The first

is made use of with grease and emery, which gives a coarser sort of polish. The second is used with crocus and water to give the proper finish to the surface. If the blades of the scissors are required to be polished, which is frequently the case, they are again sent to the first grinder, who polishes them upon a polisher similar to those described for razors and penknives. It will be here proper to remark that the shanks of the above kinds of scissors, being soft, cannot assume the polish with crocus, as nothing but cast-steel in the hardened state is susceptible of that peculiar lustre. An imitation of polishing is, however, given to the soft shanks by means of a burnisher of polished hardened steel.

The more delicate and finer sorts of scissors, in order to render all the parts susceptible of polishing, are hardened quite up to the bow, in consequence of which the order of manufacturing is a little varied, from that of the scissors having soft shanks. After being forged, filed, and having the hole drilled for the screw, the insides of the blades are ground, and they are fitted and screwed together. They have next to be hardened and tempered, and as it is a common property of steel to warp during that process, the two sides of the scissors are firmly bound together by means of iron wire. The screw being withdrawn, which would be liable to be hardened along with the scissors, they are heated red-hot all over, and immersed in water up to the bow.

After being thus hardened they are heated, for the purpose of tempering them till the blades appear of a purple and the shanks of a blue colour. The wire is then taken off, and the scissors are finished by processes similar to those above described, with the difference of the shank being polished with crocus along with the blades. After the scissors return the last time from the grinder they only require to be sharpened, wiped clean and screwed together. Previous to wiping, however, they are generally put into pulverized quick-lime, which greatly tends to the preservation of their lustre by absorbing the moisture from the surface; the presence of which is well known to facilitate the rusting of polished steel.

Some of the very fine scissors are elegantly and variously ornamented. Formerly they used to be ornamented with studs of gold or polished steel, arranged round the joint of the scissor or along the shank.

The studs are each furnished with a small tang, by which they are inserted into small holes made in the scissors. The holes are made while the scissors are soft, and the studs are inserted after the scissors are polished.

More recently the same parts are inlaid with circular bits of gold, which are polished along with the scissors and afterwards ornamented on the surface by engraving. Scissors are also ornamented by means of gilding, bluing, and etching. The gilding is performed in two ways; the first by dipping the finished article into a solution of muriate of gold in alcohol; the second with metallic gold laid on by means of heat. The first kind of gilding has been rejected on account of its want of permanency. The second, though very durable, is objectionable on account of the heat employed in the process, which is so great as to make the scissors too soft.

Various devices, such as letters, coats of arms, &c. are sometimes put upon scissors, but more frequently upon razors and swords, by means of etching. The figures are drawn upon the polished surface with a varnish, made by dissolving resin in oil of turpentine. Every other part of the articles is covered with the same varnish, excepting what is to form the ground of the picture. The exposed part

is then covered with dilute nitric acid, which is suffered to remain upon it till it is supposed to be sufficiently corroded. It is then rinsed in water to take away the acid, and the varnish is removed by means of oil of turpentine. The ground of the picture appears of a dead white, while the figure, and other parts of the article, display their original polish.

Cutlery made of Pig-Iron.

Great quantities of various kinds of cutlery have been made of pig-iron, by means of casting, particularly forks and scissors. The models are made of lead, alloyed with a little antimony. The articles are cast in sand, in flasks similar to those used in casting small articles of brass. The metal employed is of that sort of pig-metal known by the name of No 1, from the large quantity of carbon contained in it. It fuses at a lower temperature, and becoming more liquid on that account, it is the only kind which can be used for small articles.

The metal is fused in crucibles of Stourbridge clay, in the common air furnace employed in iron foundries. The articles, when cast, are almost as brittle as glass. This, in a great measure, is occasioned by the moisture in the sand, which effects this change upon the metal in a manner similar to that by which steel becomes hardened. In order to obviate this hardness, the castings are cemented with ashes or sand, for the purpose of annealing them. Cast-iron pots of a cylindrical shape are employed for this purpose. They are about 12 inches diameter, and about the same depth. A number of these pots are filled nearly to the top with the goods to be annealed: a quantity of fine sand or ashes is then employed to fill up the interstices, and to cover them completely, so as to exclude the air. The pots are placed in a furnace, and are surrounded with small coals, for the sake of carrying on slow combustion. They are heated very gradually to a temperature little short of fusion, and they are as gradually allowed to cool. The whole time occupied in heating and cooling is from 24 to 30 hours. They are found, after this process, to have become very soft, and to be capable of bending a little without breaking. They afterwards are finished in a manner similar to those which are forged, with the exception that they are not hardened and tempered: were they subject to that process, they would return to the same state as before annealing.

Notwithstanding the great demand which has been for cast cutlery, on account of their very low price, they are so completely destitute of utility, that ultimately they cannot fail to disgrace both the merchant and manufacturer. If a preference can be given to any of them, it is in favour of the scissors. The knives and forks are not only liable to break, but they soon turn black, and can be very little improved by the common mode of cleaning, as by the best means they are only susceptible of a miserable polish.

Various attempts have been made with a view to improve the cast cutlery, the most successful of which is by Mr. Lucas of Sheffield; and for his method he some time ago obtained a patent. By Mr. Lucas's process, the cast metal articles are converted from their brittle and crude state into malleable iron or steel at pleasure, without injuring the surface, or distorting the figure of the article. Nails of various kinds have been made in this way, more flexible and equally tenacious with those of wrought iron. This method consists in stratifying the articles, in pots similar to those employed for annealing, with an oxyd of iron. Calined iron-stone pulverized was first made use of, but was found to make the surface of the metal so rough as to render those articles useless. This inconvenience was in some measure obviated by laying

a thin stratum of sand between the metal and oxyd of iron. Any sort of earth, containing a portion of the oxyd of iron, is capable of bringing about this change. The red sand which abounds in some countries, or loam, or clay, containing oxyd of iron, would answer very well. The theory of this process is obvious. The cast-iron consists of iron and charcoal, or carbon; and it is to the presence of the carbon that we attribute the peculiar qualities of cast-iron different from those of a malleable iron and steel. The oxyd of iron, with which the cast-iron articles are stratified, consists of iron combined with oxygen. During the process of cementation, the oxygen of the oxyd combines with the carbon of the cast iron, forming carbonic acid, which is dissipated in the form of air. For the particulars of the process, see the articles IRON and STEEL.

Specimens of scissors, table knives and forks, and even penknives, have been made so complete by the above process, that the best judges could not distinguish them from those made of the best steel. An insurmountable objection, however, still remains, which will preclude the application of this important discovery in the manufacture of those articles which require a fine edge, and every other article which requires to be hardened and tempered.

This metal, previous to hardening and tempering, is equally tough with the best steel or iron, but afterwards becomes very brittle, at least much more so than we should expect from steel so apparently good. The reason of this will be explained under IRON and STEEL.

Handling of Table Knives.

The handles of table knives are made of ivory, bone, horn, and wood. They are formed in two different ways: one, by drilling a hole into the handle, and cementing into it the tang of the knife. This kind is by the manufacturers termed round tangs. The other kind of handle consists of two sides, which, when laid on each side of the tang, and paired together, form the handle. The two sides are termed scales, and knives of this kind are called scale tangs.

Iron handles are the most valuable, and in the greatest repute. The greatest part of them is made for the round tangs. These are of various patterns, such as octagon, oval, and fluted. The octagon and oval handles are filed into the intended form, and afterwards rubbed first with fine sand and water, and afterwards with powdered chalk and water. The fluting of the handles is performed by means of a sharp tool of the scraping kind, having the figure of the flutes upon its face.

The tangs are cemented into the handles with rosin mixed with whitening.

A very convenient and durable handle is made of stag horn. The round parts of the horn which are of proper thickness are selected for the round tangs. The outsidcs of the other parts of the horn are cut into scales, which make the scale tangcd handles. The surfaces of the stag-horn handles are invariably left in their natural state.

The small end of the ox-horn, termed the tip, is generally employed for making the handles of table knives. The tips are formed into hafts of a great variety of patterns, by means of pressing between two dies. This advantage is obtained from the well known property of horn being so soft and ductile when hot, as to admit of considerable extension. The dies employed for pressing the horn are represented in *fig. 2*. A and B, the upper and lower dies, are made to form the bits of a pair of tangs, on the even faces of which the exact figure of the handles is formed, as represented in the figure.

The pieces of horn intended to be pressed are first softened

in hot water, and then cut to the size deemed requisite exactly to fill the mould. The dies are heated to the temperature of about 400° Fahrenheit, or something short of the heat required to burn oil. The horn, with a little oil, is then laid between the dies, which are placed in the pressing vice, *fig. 3*, consisting of a compound lever, acting with a screw at A, and turning round the handle B, similar to the common vice. The force required to be given at the handle is not more than what a man may perform with ease. The motion being now reversed, the tangs are withdrawn, and the horn is found to have received the full impression of the die.

If the handles are plain, and the horn be native black, the first pressing is sufficient; if, however, they are not sufficiently black, they are dyed after the first pressing in a liquid, containing logwood and green vitriol. The process of dyeing takes off that smooth glossy surface given by the dies, which is restored by pressing them a second time in dies a little less than those employed for the first pressing. If the handles require to be fluted, or otherwise ornamented, they are pressed a second time in dies containing the intended figure.

The above handles, after they come from the press, require only to have blades inserted, and to be polished by means of rotten stone or chalk and oil.

The handles of bone are made from the shank of the ox. The thickness of the solid parts of the bone is never sufficient to make the handles equally thick with those of ivory. Some of the bones are very dense and hard, but can always be distinguished from ivory by the colour. Such handles, in order to correct their defect in colour, are dyed green in liquid, consisting of the oxyd of copper dissolved in aqua ammonia. The hartshorn of the shops, being the cheapest preparation of ammonia, is always used. The proportion are about seven ounces of the oxyd of copper to one gallon of hartshorn.

After dyeing, the blades are cemented into the handles, which are afterwards polished. When the dye does not contain any substance capable of rusting the blade, the handles are dyed after the blades are inserted.

Various kinds of wood are employed in making the handles of table knives. The very common articles have handles of birch wood, which are expeditiously made by being turned in an oval lathe. They are afterwards dyed black or red. After this they only require the blades to be put into them, and to be burnished with a smooth stone, termed blood-stone. A superior kind of wood handles are made of various foreign wood, such as lignum vitae, ebony, &c. Handles are sometimes made of very thin silver in the sheet, and of plated copper. The thin metallic shells, which form the outside of the handle, are made in two halves, by being forced into a steel dye, by means of lead; the two sides are afterwards soldered together, and the hollow part filled up with a cement of rosin and pulverized brick. The cement serves to give firmness to the thin shell of metal, and at the same time to secure the blade.

Handling of Penknives.

The handles of penknives in general consist of three parts, *viz.* the outer scales, the inner scales, and the spring. The outer scales, which are only ornamental to the knife, are made of various substances, such as horn, stag-horn, ivory, bone, tortoise-shell, and pearl. The two latter substances are employed for the most valuable knives. The beautiful variegated horn stands the next in estimation. But the most durable scales are made of stag-horn.

The inner scales, which serve to give firmness and dura-

bility to the knife, and to which the outer scales are attached, are made of iron, brass, and sometimes of silver: the ends of the inner scales intended to receive the blade is in general made thicker, and is termed the bolster of the knife. The scales of those knives having no bolsters are cut out of thin plates of the metal of which they are made. Iron scales with bolsters are forged with the hammer.

The spring is of steel, running along the back (and in single blade knives round the end) of the handle, and serves to separate the scales from each other; and by its elasticity exerted upon the tang of the blade, it secures the knife in the situations of being shut or open. The inner scales and the spring being forged, and the outer scales being provided, they are put into the hand of a workman, who finishes the whole of the handling department.

His tools consist of a vice, a small anvil, and hammer, a variety of files, steel burnishers, a breast-plate, drill-bow, and drills of various kinds; a glazer coated on the face with emery and glue, to polish the different parts; and a buff, which is an instrument similar to a glazer; but instead of being coated with emery and glue, it is used with oil, and fine sand, and rotten-stone. It is employed to polish the surface of the outer scales. The buff and the glazer are turned by the foot, in a manner similar to that of the common street-grinder. He is also provided with a number of hardened steel plates, about one-twelfth of an inch thick, and in shape corresponding to the different patterns of the handles: each plate contains holes in situations answering to the holes in the handle, by which the spring and blade are secured in their places. The inner scales are each secured to one of the plates above, for the sake of drilling holes through them opposite to the holes in the plate. The scales are then fastened on each side of the plate by temporary pins, and the edges are filed down to the plate. By this means the handles are made exactly of the pattern required. The spring is next drilled, placed between the scales, and secured in its proper situation by temporary pins, till it is filed quite level with the edges of the scales. A hole being drilled through the tang of the blade, one of the above pins is taken out, and the spring thrown back, so as to allow the blade to pass between the bolsters, in which situation it is fastened by means of a temporary pin. The tang is then filed square, to correspond with the bolster and the spring.

The blade, the spring and the scale being properly adjusted to each other, the different parts are separated by taking out the pins.

All the visible parts of the spring are next filed smooth, and the spring bent a little inwards, for the sake of giving it greater power when placed in its intended situation. The spring is then hardened, by heating it red-hot and immersing it in water; it is afterwards tempered, by rubbing it over with grease, and heating it till the grease inflames: the visible parts being glazed and burnished, the spring is deemed finished.

Our next process is to place the outer scales of horn or other substance upon the inner scales.

Scales of horn or tortoise-shell are heated, and exposed while warm to the action of a screw-press, for the purpose of making them flat.

The scales are then made of uniform thickness, by means of filing. In the next place, the shield of tin or silver is introduced.

As this is a process of some ingenuity, at least so far as concerns the forming a recess for the different shaped shields, we shall describe the tools employed, with the assistance of the following figures.

Fig. 2. is a plate of hardened steel, about one-twelfth of an inch thick, and of breadth and length suitable to the size of the shield. A hole is made through the plate exactly of the figure of the shield; and every different pattern of course requires a different plate. *Fig. 3.* represents the drill employed to cut the intended figure in the horn or other substance.

This differs from the common drill, in having the springs fastened into the part B, by means of two screws, A, A. The ends, b, b, are made sharp like the points of a drill, and are capable of boring up to the shoulder a a. The plate, *fig. 2*, is placed upon the scale, and fixed in the vice; the springs of the drill are then pressed till the ends, b, b, enter the hole of the plate. It is plain that if the drill be pressed and turned round, that the force of the spring will cause the cutting parts to make a figure the same as that of the plate. The depth of the recess is limited by the shoulders, a, a. The silver shields are cut out of the sheet by means of a punch; those of tin are first cast, and afterwards struck into a recess made in a die by means of the plate and drill above mentioned.

The shield being secured in its proper place, the outer scales are pinned upon the inner ones; the compound scales are next pinned together with the temporary pins, and both their edges are filed and finished together. They are again separated, and the insides of the inner scales polished; after which the blades, spring, and scales are all riveted together. The next thing is to file and burnish the joint and bolster; and lastly, to finish the outer scales. This is performed by filing, scraping, and buffing, first with fine sand, and lastly with rotten-stone.

Handling of Razors.

After the blades of razors are ground and polished, they only require to be handled and set or sharpened.

The handle of a razor consists of two sides, called scales, which are made of various substances. The most valuable are made of pearl, tortoise-shell, ivory, and native horn. The handles of the greatest quantity of razors, however, are made of pressed horn, some of which are dyed black, and others spotted to imitate tortoise-shell, and hence are termed mottled shell. Pearl is a substance very seldom made use of for the handles of razors. In the first place, they are very expensive, on account of the very high price of the shells; and secondly, they are very liable to be broken, as well in manufacturing as when in use. Ivory makes a very neat handle; but their very great expence in manufacturing, added to the great price of the raw material, renders their price very high. In the opinion of most, they are not neater, nor by any means so durable, as the handles of pressed horn. Tortoise-shell makes a beautiful handle, when used in the state in which it is cut from the shell; but on account of its high price, it is used with more economy by pressing it in a manner similar to that of horn. The pressing, however, deprives it of a great part of its beauty. No handles for elegance and durability can exceed those of native horn, when the specimens are properly selected for the purpose. Since, however, the handles of pressed horn are in no way objectionable, but, on the contrary, are the most generally preferred, we shall be more particular in the description of this branch of manufacture.

Having already described the process of pressing the handles of table knives, and since the scales of razors are pressed by a method strictly similar, it will be unnecessary to give a separate description.

The dies in which the scales of razors are pressed are made to press one pair at a time. The pieces of horn in-

tended for pressing are in the process sometimes extended as much as two inches.

The handles of pressed horn are divided into three varieties, *viz.* the native black, consisting of horn which is black previous to being pressed; those of the second variety are such as are dyed black, or other colour, after being pressed; and handles of the third kind are those destined for mock shell, for which the most clear and colourless scales are selected.

Those of the first kind, after pressing, retain their native black, and are much esteemed for their permanent colour. The scales, which are partially coloured, are generally dyed black with a dye made of logwood and sulphat of iron: some are dyed red, and others green. The former are dyed with archil, and the latter with indigo dissolved in the sulphuric acid.

The imitation of tortoise-shell is performed by a process called spotting, which consists in the application of a composition to the surface of the horn, by which it becomes irregularly coloured.

The compound consists of one part of minium, four parts of common pot-ash, and ten parts of quick-lime: as much water is added as will give it a pulpy consistence. It is then laid upon the upper surface of the scale with a stick: as carefully as possible, and is spread thicker in some parts than in others, for the purpose of giving a variety of shades. The substance is allowed to remain upon the surface for six or eight hours; and the latter part of the time they are placed before the fire. After the composition is removed, the surface exhibits a striking imitation of tortoise shell. The singular effect of this substance is evidently the result of some chemical change. The lime appears to answer two purposes: it takes the carbonic acid from the pot-ash, and at the same time serves to give a proper consistence to the mass. The lead and the pure pot-ash together are essential to producing the effect; though, when separately applied, no change is observed. The fact is, that the colour is produced by the dissolved oxyd of lead in the alkali. A colourless solution of this kind may be advantageously used for the spotting of horn. May not this compound be found of use in giving colour to other animal substances, such as hair, leather, &c.?

The handles of razors are frequently ornamented by means of shields of various figures, some of which are of silver, others of yellow metal, and of an alloy formed of lead and tin. The silver and yellow metal shields are pressed into the substance of the horn by means of a press similar to a fly-press. The scale and the shield are placed between the two dies of a figure corresponding with the shape of the scales, the dies being previously heated to a temperature something short of that employed in the first pressing. A sufficient force is then exerted upon the screw to force the metal into the horn. Figures, letters, and other ornaments, are introduced by the same method.

The shields of lead and tin are put in by first making in the scales a proper recess, by means of the spring-drill described in *figs.* 2. and 3., and afterwards filling it with the melted metal. The greatest number of shields are of this kind.

The handles of pearl, ivory, &c. which cannot be made by pressing, have the proper shape given to them by means of the file. The shields are then introduced by first making the proper recess with the spring-drill, and afterwards securing the shield by means of rivetting, but more completely by the following method. After the shield is cut out to its proper shape, it is made concave on one side, and convex on the other; at the same time the edge is a little

bevelled towards the convex surface. The cutting part of the spring must be so formed as to make the bottom of the recess to receive the shield a little larger than at the top. The shield being then introduced with the concave side downwards, and hammered upon the convex side, becomes firmly secured.

The scales of the handle in the state already described are now fit for the reception of the blade. A piece of white metal, an alloy of lead and tin, called the head, is next placed between the scales at one end, to allow the blade to go between when the razor is shut; the blade is then screwed in its place, and the scales fastened together by means of rivets, which are of iron, brass, and sometimes of silver. Zinc wire has been recently used for the purpose, and receives a good polish. The handles of razors in the state left by the press and the file are first scowered with sand and water, and afterwards polished upon a buff.

A superior kind of fine cutlery is manufactured in London, chiefly by the surgical instrument-makers: the excellence of which consists in the great attention paid to its fabrication; the quality of the steel, and above all to the correctness of the several temperatures under which it is hardened, and the reduction of this by the process called tempering.

The estimation these articles are held in, allows the manufacturer to employ the superior workmen, and also to reject, during any part of the process of manufacture, such articles as from slight flaws, cracks, or even any inferior quality in the steel, may be objectionable.

The process of the manufacture differs also from the circumstance of the same workman beginning and completing the article. Engines and complicated machinery are never used: therefore his skill and abilities being exerted, greater perfection is obtained. The hardening of steel depending on the quick abstraction of the heat given, different mediums are made use of, as quicksilver, water, oil, &c. The tempering, or reduction of the hardening, is not governed by the colour only, but by a more accurate method (proposed by Hartley); the exact variations of temper are given in a fluid, into which a Fahrenheit's thermometer graduated to the boiling point of mercury is immersed, and the delicacy of this operation may be sufficiently understood, from the various colours produced on the steel, at the various temperatures shewn by the thermometer. The change or scale takes place at 430, and finishes at nearly 600. Nine changes of colour are observable at about 20 degrees distance of each other, *viz.*

430 Slight colour inclining to yellow.

450 Straw colour, pale.

470 Yellow.

490 Brown.

510 Brown with purple spots.

530 Purple.

550 Bright blue.

560 Blue.

600 Blackish blue inclined to scale or oxyd.

From 430 to 470 is chiefly employed for razors, and some of the finer edged surgical instruments.

470 and 490 for penknives, and some pointed instruments.

From 510 to 550 includes pocket-knives, table-knives, carvers, scissors, &c. &c.

The experience of the workman is much required, and also a knowledge for what purpose the edge is to be employed, during these three ranges of temperature.

550 and 560 Spring temper.

Setting.

The operation of setting an edged instrument, is the giving it a more permanent, or lasting edge, by means of a hone, or any other fine cutting stone. Every article is left from the wheel with a thin wiry or notched edge. This must be removed, and one substituted of an angular form; the more obtuse the angle, the stronger the edge, and *vice versa*. This angular edge is obtained in several ways; sometimes by the thickness of the back of the instrument, but more generally by the elevation of the back from the stone.

Razors are set upon a stone brought from Germany. Their backs being thick, they are laid perfectly flat, and rubbed backward and forward on each of their sides, till the wire or notched edge gives place to a fine smooth one. The use of a small quantity of oil on the surface of the

stone is requisite.

Penknives are set upon a stone brought from Turkey, and from its property of absorbing oil, it is called an oil-stone. They are held at an elevation of the back just sufficient to keep it from touching the stone; and the greatest attention is here requisite, to give them the same exact elevation, during the removal of the wire edge. They have also a few strokes given them as a finish, upon a hard kind of green stone.

Scissors are set upon the oil-stone; they are held nearly upright, that their edges may be turned toward their inner side.

Pocket-knives, carving, and table-knives, are set at an elevation, upon a stone, called a rag-stone, of a fine sandy texture, and without the use of oil.

CUTLERY.

PLATE I.

Fig.1. Two Troughs of a Grinding Mill.

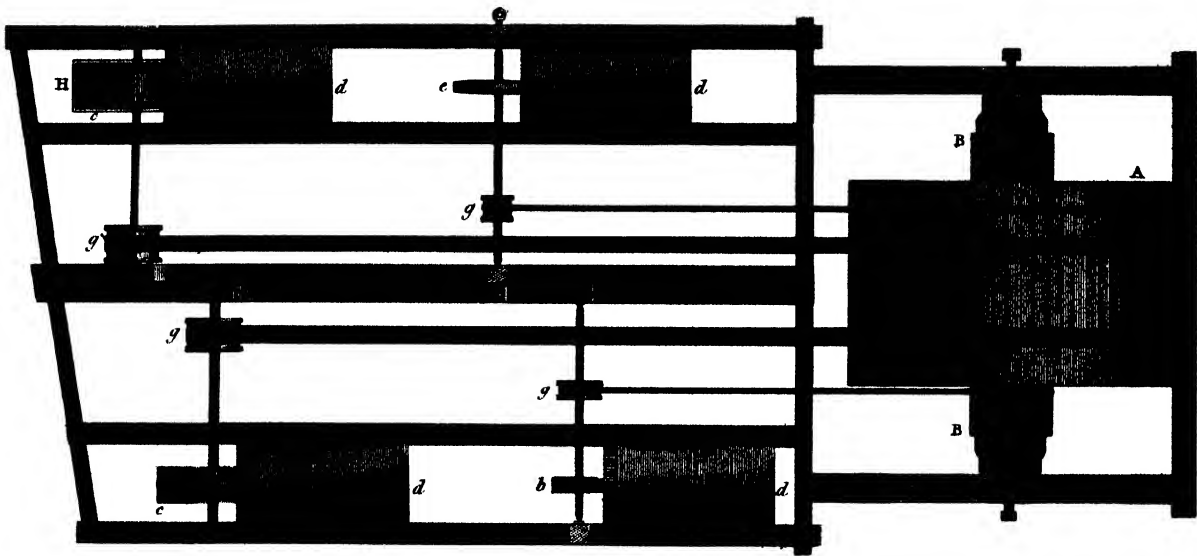


Fig. 3. Pressing Vice

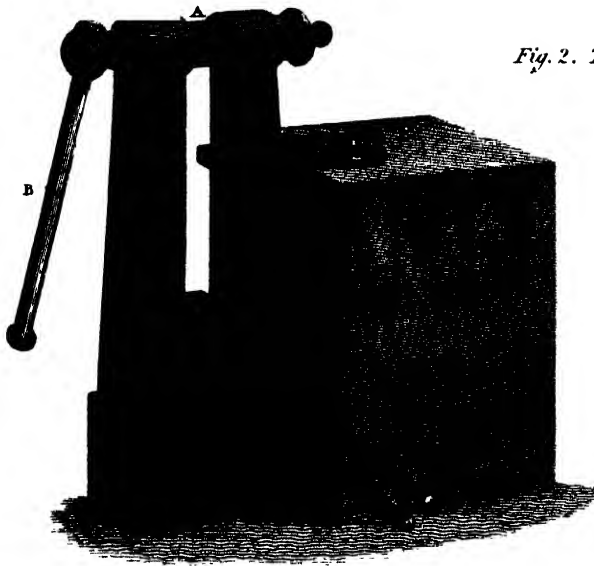


Fig. 2. Tongs for pressing Knife Handles.

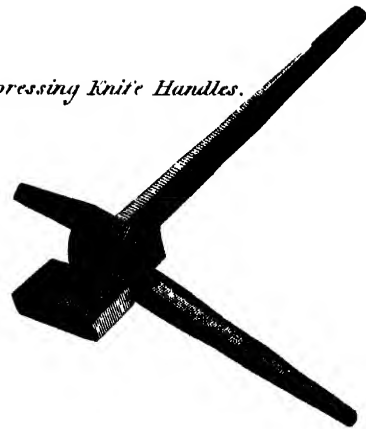


Fig. 3. Spring Drill.

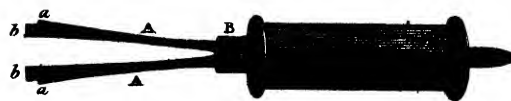


Fig. 2.



Cutting-engine

CUTTING-Engine, in *Mechanics*, is the name of an engine, which divides and cuts a wheel, pinion, or rack, into any assigned number of teeth, which office it performs both with accuracy and expedition. While the art of constructing wheel-work was yet in its rude state, the dividing of a wheel into the requisite number of circular parts, and cutting away the notches or spaces by a manual operation with a file, was not only a tedious but an imperfect way of proceeding, which left such inequalities in the size and shape of the tooth, as were but ill suited to transmit any applied

force in an equable manner, or to perpetuate the duration of the parts once made. To facilitate such manual operation by a file, the simple platform was invented, described by father Alexander, in his book on clock-making, which was a circular plate of brass, from ten inches to a foot, or more, in diameter, with as many concentric circles thereon, as the usual numbers of teeth in the wheels and pinions of clock-work required to be divided into corresponding parts of a circle. In the centre of this platform was fixed a stem, or fast arbor, round which an alidade, ruler, or index, with a straight edge, pointing to the centre, turned freely into

any given point of a required circle, by means of which the divisions of any given circle were transferred to a wheel, placed on the said stem under the said index, by a marking point. This mode of dividing a wheel is still imitated by the enamellers and engravers of clock-faces, and is certainly an easy way of transferring divisions from a larger to a smaller circle for various purposes, where the accuracy of an astronomical instrument is not required; but still the spaces were required to be cut by hand with a file; at length a little frame was mounted on the index, which was contrived to direct and confine the file in such a way as to cut the notches of a wheel, placed over the index, with less deviation from the truth than could be managed by mere manual dexterity; this addition, no doubt, led to the adoption of a circular file, or cutter, and of such other appendages as completed the construction of a simple cutting-engine; and it is asserted [“*Etreennes Chronometriques*” par M. le Roy] that Dr. Hook was the first person who contrived such an arrangement, as could merit the name of a cutting-engine, [machine a fendre.] The doctor’s invention, which, like many other of his inventions, has proved to be of permanent and great utility in mechanics, consisted of an entire transmutation of the old stationary platform, with its moveable appendages, into a moveable platform inserted into a strong metallic frame with stationary and additional appendages; the machine thus converted into an engine, or self-acting piece of mechanism, consisted of the strong frame; the sliding supporting bars of the platform, or plate, with an horizontal screw of adjustment for distance from the circular file; the divided plate with a revolving arbor to receive the wheel to be cut; and the alidade fixed to the great frame, in the position of a tangent line to any of the divided circles, and applying its bent and rounded point to the punched marks of division on the circle successively, as the plate revolved, in the act of cutting the successive teeth of a wheel. This construction of the engine is very nearly the same that remains in the tool shops of the present day. The original divisions of the circles, viz. 360, 300, 150, 90, 60, &c. are also retained in the ordinary engines, though many of the smaller numbers are included in the larger ones, and are therefore superfluous; for taking every fourth hole of 360, is the same as using the circle of 90, or every sixth the same as using the circle of 60; also taking every other hole of 300 is the same as using the circle of 150. As these ordinary engines are very limited in their operations, by reason of their powers extending only to the numbers marked on the divided circles; and as the prime numbers are not usually inserted, we find that different ingenious men, both in France and England, have contrived additional apparatus to render the engine more perfect. Indeed so long ago as the year 1716, Henry Sully brought into England, among his collection of new tools, a superb engine, made by M. de la Faudière, which has been mentioned by Julien le Roy, and described by Thiout in his “*Traité d’Horlogerie*.” About 1730, M. Taillemard made further improvements in the cutting-engine, particularly by introducing a tubed arbor instead of an arbor with a square hole, which had been usual before. After Taillemard, his apprentice Hulot continued to construct engines in a superior way in France, and is succeeded by his son Hulot the younger, whose execution is deemed equal to that of his father.

M. Fardoil, another French mechanist, contrived a plate to his engine, which afforded the means of cutting any number of teeth in a wheel, prime or composite, by a circular rack and endless screw, the latter of which is fixed in a stationary position. The description of this engine is

given in Thiout’s work which we have already mentioned, to which the curious reader is referred for a full account. The number of notches on the circumference of the plate, which has no divided circles, is stated to have been 420, so that one revolution of the screw answered to a tooth, where the wheel was required to be cut into 420 teeth, and in proportion as the micrometer-head of the screw was turned more or less than an entire revolution, were the teeth reciprocally fewer or more numerous than 420. This number seems to have been chosen in preference to any other, by reason of the many composite parts it is capable of being divided and subdivided into. In practice it was necessary to divide the number 420, and also the number of teeth of the proposed wheel by some common divisor, in order to reduce the terms into their lowest denomination; then the quotient arising from the number of the wheel’s teeth, in using the common divisor, was made the number for the divisions of the micrometer-head, and the larger quotient coming from the term 420, was the proper number of divisions of the said divided micrometer-head necessary to pass the index after cutting each tooth. An example will render this mode, which was certainly ingenious, intelligible to any ordinary reader, who has seen an engine. Let the number of teeth to be cut be 249, then the common divisor

will be 3, and $\frac{420}{3} = 140$, likewise $\frac{249}{3} = 83$; the smaller

quotient therefore 83 is the number of divisions proper for the micrometer-head, fixed to the axis of the endless screw, and 140 of those divisions must pass the index after each cutting operation; the result in this case will be the same as if the micrometer had had 249 divisions, and 420 of these had passed the index after the cutting of each tooth. The micrometer-head had a ratchet wheel and contrivance for making number *one* of the divisions come back to its original situation after each operation, like the contrivance in the engine for dividing sextants and nautical circles, which engine will be seen in another place. This mode of cutting all kinds of numbers, ingenious as it is, requires, however, various micrometer-heads to suit such prime number, which prime numbers themselves require dividing previously; consequently the real advantages of this contrivance are by no means adequate to its professions. Berthoud has given a description and drawing of a French machine for cutting the teeth of wheels and pinions, in his “*Essai sur l’Horlogerie*,” and also in his “*Histoire de la Mesure du Temps*,” such as he considers of the best construction; and in his “*Traité des Horloges Marines*,” he has described an apparatus for forming the ends of the teeth by means of a concave file confined in a frame, which makes it move in a given direction; which description, together with the drawing, is copied into his “*Histoire de la Mesure du Temps*.” We satisfy ourselves with a reference to these contrivances, in order to describe two engines of English construction, which have not been previously described, and which, we think, merit a particular notice, both as specimens of ingenuity, and as engines of great utility in daily practice. These engines we have already referred to under our article *Clock-making*; one as being used by the late Brown of King-street, Seven-Dials, London, which we learn was projected, and partly made between the years 1770 and 1780, by Hindley of York, when in London; and the other, as being contrived by the late Rehé, mechanist to the naval board of works, and purchased by Troughton for the use of a relative, who is since dead, and who is succeeded by James Fayer of No. 35, White Lion-street, Pentonville, who now uses it. On a reference to Mr. Troughton’s books, we find, that his late brother divided Rehé’s engine-plate in

the year 1783, which fixed the date of its construction; and from this as a model it was, that the inventor constructed a similar one for Dr. Milner, the dean of Carlisle, of the expense of which that gentleman had not formed a competent judgment at the time he gave his order, to make as good an engine as could be constructed, which occasioned some demur about the payment. The worthy dean little suspected that the engine he had ordered would cost him three hundred pounds or guineas; and the reader will not be less surprised to be told, that Rehé's engine, with its apparatus, was sold at his sale for 700l.

Cutting-Engine by Hindley.

The cutting-engine contrived by Hindley is represented in *Plate II. of Engines. Fig. 1*, is a perspective view of the entire engine in a state proper for cutting, with the exception of the foot-wheel surrounded by the cord that gives motion to the revolving cutter, and of the bench to which that wheel is attached, and on which the engine rests; but the reader who has seen a common turning-frame, or other mechanism turned by the foot, can readily conceive how a similar motion may be given to the cutting-engine by a lever, placed nearly horizontally under foot, and connected with the crank of the large wheel's arbor: *figs. 2 and 3*, shew the cutter frame detached from the engine, the first of which supposes the eye placed over it, and the other at one end when viewing it; we shall speak of them more minutely, and also of some figures in *Plate III.*, when we have described the engine in its entire state.

A B C D E F is a strong iron frame, fixed by the end pieces at E and F to a steady bench, to which also the large wheel for the cord is fast, but not seen in the drawing; the side-pieces of the frame, A B and C D, are exactly parallel to each other, and their upper edges are terminated by two slopes that form an oblong and obtuse wedge, on which the sunk base of the cutter-frame, G H I K, rests, and slides smoothly when one of the handles and micrometer head at L turns the horizontal screw, between B and D, that is tapped into a piece of metal behind the cutter-frame and attached thereto. M is a strong tube of brass fixed to the side of A B by four screws seen to the right and left in the square part to which the tube is fast: within this fixed tube M there is another tube N seen above it, which constitutes the revolving arbor of the large circular plate O, under the frame; the annular shoulder-piece, P, resting on the top of tube M, and pinned or screwed fast to the interior tube N, bears the whole weight of the plate O: a section of these tubes, containing another tube and arbor of a pinion to be cut, is given in *fig. 1. of Plate II.* The plate, O, is about a foot in diameter, and marked into a number of divided circles, with holes drilled through at each divided point, the use of which will be explained presently. Through the inner tube N, or axis of the plate O, passes a solid arbor on which the plate, Q, is fixed, with a few notches cut on one side; this solid arbor is fixed by a screw, under the centre of the plate O, as seen in *fig. 1. Plate II.*, and may be taken out at pleasure, and a projecting pin fixed in this solid arbor, below the wheel, takes into a corresponding notch made in the tube N, which contrivance makes the solid arbor and tube, N, rest or revolve together, as circumstances require, and also along with them the circular piece of metal Q, placed fast to the solid arbor by a collet and tapped nut screwing down upon the superior end of the arbor, formed into a screw, as seen in the figure. Of these solid arbors there is a variety belonging to the engine, with their superior ends varying in thickness to suit the different holes of different plates Q, or in other words, to suit the central

holes of different wheels previously turned and fitted to their respective arbors; but it is not necessary to introduce those different arbors into our drawing, as their shape is common, and their dimensions vary only at the superior end, where the wheel fits. In consequence of the connection of the solid innermost arbor with the tube N attached to the platform or divided plate O, whenever this plate revolves a given quantity, or division of one of its circles, the wheel fixed to the solid arbor, above the frame, moves with it precisely the same portion of a circle, and presents itself to the cutter or revolving circular saw R, borne by the moveable frame G H I K, and having a small pulley round the posterior end of its arbor, which is seen embraced by the cord that puts it in motion. Whenever the handle S, attached to the cutter-frame, as may be seen more clearly in *fig. 2*, is lowered by hand, the cutter, R, descends with it till meeting with the edge of the plate, or wheel Q, it cuts a notch through it, while the moving pulley gives motion to the said cutter; as soon as this notch is cut, the depth of which is regulated by the screw of the handle L, that moves the whole cutter-frame, the handle, S, is permitted to ascend, which it does by means of a spiral spring seen in the middle of the cutter-frame pressing under the top portion in *fig. 2*; the cutter is then free from the notch of Q, and the latter is at liberty to advance round whenever the plate, O, is moved; during this time an index, with a fixing point, T, called by the French an alidade, holds the plate in a firm position, in consequence of the point, T, penetrating one of the drilled holes of the divided circle, made choice of for the operation; this point, T, is next raised by the right thumb pressing on its opposite end at U, while the fingers of the same hand turn the plate, the space of one division or more as may be required; the left hand in the mean time grasping the handle S, and the foot continuing to turn the large wheel, that is the first mover; the motion of the large plate has now brought Q, the wheel to be cut, a corresponding space round, to the situation required for cutting another notch, which the cutter immediately does on being brought down by S, the handle for the left hand, into contact; the operation of raising the fixing point T, and of moving the large plate O, another division, is repeated, and the wheel, Q, is again in a situation to have its third notch cut; and thus the operations of moving the large plate and lowering the revolving cutter are alternately repeated till there are as many notches cut in the edge of the wheel, as the divided circle contains drilled holes of division, provided the plate is turned only the space of a single division; but when the plate is moved two divisions of the circle every time the point, T, is raised, then the number of notches cut in the wheel will be only half the number of such divisions; so that any divided circle on the plate will serve for a wheel that is either the whole number, or any exact aliquot part of that number. For the ordinary engine this description would have been sufficient to have conveyed to the reader an adequate idea of the operation of cutting a wheel fit for all common purposes; but the engine before us is comprehensive in its uses, and takes in all numbers prime and composite, whether divided on the plate or not, which lie under 360, its greatest number of divisions in one circle; nay, it will go even beyond this number if found necessary, as will appear from a little closer inspection. In an ordinary engine, the fixing-index, or alidade, is made elastic, and placed on the side of the principal frame, and is moveable on the end opposite to the fixing point, so as to be capable of being placed as a tangent line to any one of the divided circles, but has no screw or micrometer to alter its length or position when once fixed, on which account a wheel cannot be cut into any other number of teeth, but

such as are laid down on the plate, or such as are derived from those, by taking every second, third, or fourth, &c. hole of the divisions; whereas in the engine before us the fixing index, U T, is not attached to the frame, but to the four-armed piece of brass V W X Y, that is moveable round the inferior end of the fixed tube M at V, and connected with a worm-screw by means of teeth cut on its branch Y, as shewn in the figure; the worm near Y is fixed by a cock to the end-piece E of the large frame, and has a micrometer head, Z, divided into sixty notches, instead of dividing lines, that the elastic index *f*, above Z, seen screwed to the said end-piece of the frame, may make such a noise in passing the said notches of the micrometer-head as are audible to the workman, who therefore has no need to examine the dividing marks by the eye in the act of cutting. The branch, X, has an oblong hole in it, that the contiguous end of branch Y may be adjusted in it, by fixing the racked end near Y in a proper situation to act freely with the worm-screw when wanted; the piece of brass *a*, with a long open in the middle, and screwed at *g* to the side, A B, of the principal frame, has the screw, *d*, passing through it to fix the branch X, whenever the worm-screw is not required to be in use, which in this case fixes the index, T U, to the frame A B, but when the worm is used, as hereafter described, the thumb-screw, *d*, is turned back. The arm W b, to which the index and fixing point, T, are attached, slides in the adjustment for a given circle to be used on the plate O, along an under bar of similar dimensions, which it covers, and which is a part of V continued; the interior end of W b is kept to its direction by the fixed clamp, *b*, that moves on pivots near the letter *b*, at one side, and has a fixing point that penetrates the holes of division made and numbered, along the upper or sliding bar, with figures that indicate the divisions of any given circle to which the fixing point, T, of the fixing index is at any time placed; therefore, when a wheel is required to be cut into any number of teeth, found upon the divided bar W b, this bar is slid in or out, while the fixing point of clamp *b* is held up, till the hole designated by the required number falls under the said point, in which situation it is made fast by the thumb-screw *e*, and the point, T, then falls into one of the drilled holes of the proper circle of plate O, which in ordinary engines contains the numbers itself. The index, T U, of the fixing point of the plate O, turns on pivots above *b* when pressed by the thumb at U, and has a spring underneath that makes it return, and holds it fast in any assigned hole of a given circle of the plate during the cutting of a space in the wheel required to be cut; but when the plate is wanted to be at liberty to move a large portion of a revolution for any purpose, the spring just mentioned can be locked, so as to hold the point, T, above the plane of the plate, till the act of cutting commences. By the help of this appendage to the engine a wheel may be cut into a number of teeth not divided on the plate in the following manner; suppose a wheel of 62 teeth were required to be cut, and that there were no divided circle on the plate nearer than one divided into 60 holes, to cut it from; then having fixed the wheel on the solid arbor by the fixing nut, in the situation of Q, and having slid the divided bar W b till the fixing point of *b* falls into the hole designated by 60 on the said bar, let it be fixed there by the thumb-screw *e*, and let the point T fall into any one of the holes drilled in the circle 60, which will now be exactly under it; also let the thumb-screw *d* be turned back to set the four-armed piece at liberty to move by the worm-screw Y attached to the micrometer-head Z; in this situation of the apparatus cut a notch in the wheel, then press on the end U of the index and carry the plate in the direction from O towards T, the quantity of two divisions,

which will be two teeth in the wheel if they were cut, the cutter in the mean time being raised from the wheel, as in the drawing: turn in the next place the micrometer screw, and count the turns and parts of the micrometer until the wheel is brought back to its original situation; that is, till the cutter on trial is found to drop easily into the notch before cut without rubbing on one edge of the notch more than on the other. Let the turns of the micrometer thus counted be 7, and 14 notches or marks out of 60 over, for the measure of two teeth in case 60 teeth had been the number to be cut, which will be 434 notches on the micrometer-head passed over by the index *f*; then if these notches be divided by 62, the teeth to be cut there will be $434 \div 62 = 7$, for the number of notches that the large plate O ought to be turned back after each tooth is cut, in a direction opposite to that of the plate's motion, when made to revolve after the fixing point, T, is raised; the process therefore now to be used in cutting, is to raise the point T in the first place, then to move the plate from O towards T, one division or $\frac{1}{60}$ of the circle, after that to turn the micrometer back 7 notches of the 60, which carries the plate back again from T towards O, a small quantity, so as to form a tooth of $\frac{1}{62}$ instead of $\frac{1}{60}$ of the whole number to be cut. Lastly, let the notch be cut, and repeat the same process at every cutting, and it will be found at last that a wheel of 62 teeth has been cut instead of one of 60, on account of there being 62 times 7 notches in the 434, that have in the whole passed the index *f*, during the time that the wheel has been under the act of cutting. Should it happen, as will generally indeed be the case, that there is a remainder in the division of the notches by the teeth of the wheel to be cut, the remaining numbers may be intercalated thus: as a second example, let the number of teeth be 61 to be cut from the same circle of 60, and let the turns of the micrometer, as before, be 3, with 37 notches over, out of 60, for the space of a single division on the plate O; in this case there will be only 217 or half the former number of notches in the whole, to be divided by 61, the quotient arising from which is three, with a remainder of $\frac{3}{61}$, so that, properly speaking, $3\frac{3}{61}$ notches of the micrometer ought to be drawn back after every shifting of the fixing point T, but this is not practicable without a ratchet, and returning back to the micrometer, which the engine has not got; therefore as 34 is only 3 more than half of 61, and as one notch on the micrometer does not affect the motion of the plate O in a sensible manner, the notches may be taken alternately 3 and 4 in succession, except in three equidistant points of the wheel, where 4 may be taken twice in succession, which mode of interpolation of the notches belonging to the remainder, as they accumulate, may be practised with any other numbers, and the difference thus occasioned among the teeth will not be sensible even under a magnifying glass. The writer of the present article has seen and examined a wheel of 126 teeth cut from a circle of only 100 divisions in this manner, which appeared as evenly divided, as if it had been cut from a circle drilled or punched into 126 divisions.

If the number of teeth to be cut had been taken fewer than the divisions in the circle used on the plate, the micrometer-head must, in that case, have been turned the contrary way, to augment the divided spaces of the plate, and to enlarge the size of the teeth in proportion as their number is decreased, which effect can now be readily apprehended without further detail.

But this property of being capable of cutting wheels into all assigned practical numbers of teeth, is not the only advantage that this engine possesses over the common engines seen in the tool-shops: when the cutters of these engines

require to be changed, the arbor, on the middle of which they are fixed, requires to be taken out of its frame, and to be replaced and adjusted to the centre of the plate, or middle of the solid arbor, as frequently, which is troublesome: also as the cutter-arbor revolves round stationary pivot-holes, the bottom of each notch cut in a wheel is necessarily a portion of the circumference of a circle, which in a thick wheel requires to be filed into a straight line after the cutting is finished. Both these inconveniencies are obviated in our present engine. To avoid the first inconvenience, the cutter, R, is put on the projecting end of its arbor, and can be taken off and put on without displacing the arbor from its moveable frame. When, however, the cutters vary in thickness, they require an adjustment of their middle part to the middle of the solid arbor that bears the wheel to be cut, which is done by a contrivance seen best in *fig. 2*; where R, as before, is the cutter, and H I an arbor, round the pivots of which the top of the frame, to which the handle, S, is attached, revolves, and to which the said top is united by a small handle *i*; when the screws, *k* and *l*, are loose, the top of the frame, *k l m n*, is at liberty to have a motion in the direction from H to I, or the contrary; but the small handle, *i*, is screwed at the middle to the arbor H I, and at the interior end to the top of the frame, near the fork of the large handle S; so that, as the bearing parts H and I, beyond the two ends of the arbor, have no lateral motion, whenever the screws, *k* and *l*, are loose, and the end, *i*, of the small handle is moved towards H, the whole top, *k l m n*, and cutter, R, are carried towards I, and the contrary when the end, *i*, of the small handle is moved towards I; this side motion of the cutter, and of its arbor, affords the ready means of adjustment for cutting the spaces, and consequently of forming the teeth of any wheel with a given cutter, in a direction tending exactly to the centre of the said wheel; and when the adjustment is made, and examined by the notch in gauge *p*, *fig. 1*, which ought to fall on the middle of the cutter, when turned round its centre of motion at its lower extremity, the tightening screws, *k* and *l*, may be turned home again, and the cutter will remain adjusted. With respect to the other advantage of cutting the bottom of each space in a straight line, however thick the required wheel may be, *fig. 3* will furnish an explanation; here is a side view of the cutter seen less obliquely than in *fig. 1*, and detached from the other mechanism; H, as before, is the place, where the proper centre of motion of the arbor H I, in *fig. 2*, is, and R again is the cutter; the arbor of the cutter is hid, but can easily be apprehended to be admitted to pass up and down the opening *s t*, of the part, K, of the frame, as seen in *fig. 1*; while a roller or friction-wheel, surrounding the said arbor, touches the interior sides of the fork *s t*; this property of the cutter's ascending and descending in a straight line, when the handle, *s*, is raised or lowered, would however be checked by the limit of distance from R, the centre of the cutter, to H, the centre of motion; but the pieces, H and I, have also each a centre of motion at their lower extremities, as at *r*, which allow the centre H, and its corresponding one at I, to approach to, and recede from, the oblong aperture, *s t*, twice in each ascent and descent of the cutter; namely, once above its present horizontal position, and once below. The perpendicular screw at *u*, forms a stop to the ascent of the arbor, and a corresponding one below at *r*, forms a similar stop to its descent; the latter of which is also used as a limit for the depth of a contract wheel's teeth, during the operation of cutting. When a very large wheel is to be cut, there is a part of the cutter frame behind G, not seen, which is tapped, to receive the screw of the handle L, in

fig. 1, one half of which tapped piece is cut away, and allows the other semicircular part to be set at liberty from the screw, by turning on a hinge, to enable the frame to slide freely to the rough distance, without turning the screw, which contributes to expedition in the adjustment of the cutter's distance from the solid arbor that bears the wheel. In common engines it may be proper just to mention the large plate O, together with its secondary frame that supports its lower pivot, is adjusted by the horizontal screw to the cutter, the frame of which cutter remains always fixed to the principal frame.

Besides the parts above described, the engine before us has got two appendages, that render its uses still more comprehensive, namely, a contrivance for cutting pinions on the arbor, and an apparatus for cutting straight racks, with which we will finish our account of this engine.

Fig. 1. of Plate III. (of ENGINES), is an elevation of the appendage for holding a pinion on its arbor, together with a section of the concentric tubes above the large plate referred to above, but not seen. In *fig. 1. of Plate II.* A B is a portion of the principal frame, denoted by the same letters as before, M and M, a section of the fixed tube M. In *fig. 1. of Plate II.*, N and N, a section of the revolving tube N, or axis of the plate, P and P, its bearing shoulder, and Q R, a third tube, instead of the solid arbor, holding the pinion arbor fast, and fixed by the milled nut, R, under the plate O, seen now as a straight line: the stage of the innermost tube at Q, has many holes drilled into it, tapped so that not only a pinion, but a wheel also, may be attached to it, and cut, after it is fast to its arbor; of these tubes, Q, R, there are many varieties, differing in bore and size of the stage, to suit different purposes. The piece *a b*, attached to the frame A B, by two screws at *a*, has an oblong opening, receiving the sliding piece *c*, that can be fixed by a thumb-screw behind, at any height, and that admits the horizontal bar *d*, to slide through it, before it is fixed; at the part *e*, of *a b*, is a hole with a slit, that allows it to open or close by the action of the screw *f*; through this hole *e*, the steel wire, *g*, passes, and forms a bearing for the upper pivot of the arbor, *p*, of the pinion, which otherwise would yield to the cutter, while the bar *d*, pressing against the said arbor near the pinion, prevents its bending during the operation of being cut, or *slit*, as this operation is usually called, which is performed like the cutting of a wheel, already described.

Fig. 2. of Plate III. is a plan of the upper side of a small plate of brass, and of its appendages, for holding a rack during the act of cutting, and for limiting the size of the teeth to any given dimensions; *a b*, is the plate in question, mounted over the frame of the engine, near the cutter, by means of a strong bar, like *a b*, in *fig. 1*, and placed in the same situation, as may be seen in *fig. 3*, which is an end view of *fig. 2*; the two little screw-holes at each side of the letter *b*, in *fig. 2*, shew the place of attachment; and a strong screw, passing through the larger hole at *c*, enters the superior end of the main arbor of the engine plate, and fixes this mechanism steady enough to bear the action of the cutter, applied in the usual way. The bar to be cut into a straight rack lies upon this plate *a b*, from *d* to *e*, between the cocks *d* and *e*, on one side, and the adjustable bar *f*, on the other, which bar sliding in the two oblong openings, may be fixed at the required distance from the said cocks, by means of the two screws at its opposite ends taking into two nuts beneath, while a couple of thumb-screws *g*, *h*, seen in *fig. 4*, which is a side view, press above the said bar intended for the rack, and keep it firmly down. The pinion *i*, with twenty teeth, is used as the head of a micro-

meter screw, which the elastic index, *k*, rests upon, so as to make an audible sound, to serve as a reporter of each twentieth part of a revolution; it is seen in the *figs.* 2, 3, and 5, the last of which is the plane of the inferior side of the plate *ab*, and without which the whole contrivance could not well be explained in an intelligible manner: on the arbor of the pinion, *i*, is an endless screw or worm, seen in *fig.* 5, into the spiral space of which a single tooth, *l*, is inserted; the bar, *l*, which is seen pressing against the cock *c*, as a thin bar in *fig.* 2, has a joint near the pinion *i*, on which the catch, *m*, turns, when lifted by the lever *n*, which lever itself turns on a pin in the bar *l*, as a fulcrum. The catch *m*, as represented in *figs.* 2 and 5, is raised a little from the bar *l*, and has a spring, attached to the bar *l*, pressing it back again into contact with this bar; consequently the end, *n*, of the lever is now nearer to the pinion, *i*, than it would be, if the end, *m*, of the catch were not removed, in opposition to its spring, from the excavated part of the plate. The catch, *m*, which is seen covering the bar, *l*, in the side view in *fig.* 4, has an oblong opening, through which the fixing thumb-screw, *o*, passes, as well as through an opening in *l*, not seen, into the cock *c*, in *fig.* 2; and the bar, *l*, is itself attached to the plate by a sliding cock *p*, in *fig.* 5, and also by a dove-tailed piece attached to the cock *c*, in *fig.* 2, on which piece the concealed dove-tailed opening of *l* slides, when the worm is in motion. From this detail of the different parts of action, it may now be conceived, that when the pinion, *i*, is turned, its worm actuates the single tooth attached to the bar *l*, and consequently moves this bar, together with the lever *n*, and catch *m*, a quantity in or out, that depends on the direction and quantity of the pinion's revolution, after which motion, it may be fixed to the cock *c* of the plate, by the fixing screw *o*; and as the edge of this cock *c* is divided into inches and tenths, a stroke made on the contiguous edge of the bar, *l*, serves as an index to measure the tenths passed over; the thread of the worm-screw is so cut, that one revolution of the pinion draws the bar *l*, and its appendages, just one-tenth of an inch: consequently, one tooth of the said pinion, counted by the noise of the elastic index *k*, measures $\frac{1}{20}$ of $\frac{1}{10}$, or $\frac{1}{200}$ of an inch. As the same letters of reference apply to all the four *figs.* 2, 3, 4, and 5, a further description, it is presumed, is unnecessary. In using this apparatus, the cutter-frame of the engine is adjusted so, that the cutter intended to be used is brought into contact with the edge of the bar to be cut, at the excavation near the end, *m*, of the catch, and is made to cut a notch, as though a wheel were to be cut; the cutter is then raised out of the notch thus cut to a proper depth, and the pinion, *i*, is turned, so as to make the end, *m*, of the catch fall into and fill the said notch, the rack being in the mean time pressed fast by the screws *g* and *b*, seen in *fig.* 4; the lever, *n*, is then depressed, which takes the catch, *m*, out of the notch; and supposing $\frac{1}{20}$ of an inch to be the thickness of the tooth to be cut, the pinion is turned back again two entire revolutions, one for the space, and the other for the tooth, in which new situation the bar, *l*, is set fast, by the fixing screw *o*; the rack is now set at liberty, by turning back the pressing screws *g* and *b*, and the rack is moved gently by hand, towards the pinion *i*, until the catch *m*, in its adjusted and fixed situation, falls again, by means of its spring, into the same notch which it occupied before it was moved by the worm-screw; the rack is a second time pressed by the screws *g* and *b*, and a second notch is cut as before, which now forms the tooth of a requisite thickness; again the catch, *m*, is lifted by the lever *n*, the rack set at liberty, and moved till the second notch is

caught by the catch, where it is in a situation to be fixed for the cutting of the third notch, or second tooth; and thus the alternate process of raising the catch, and moving the bar of the rack, till it is caught in the next succeeding notch, is repeated before each cutting, till as many teeth are cut as are wanted; the pinion and its worm-screw having performed their whole office before the second notch was cut. When the rack is required to be cut into teeth on nearly its whole length, it is usual to begin about the middle, and to cut one half first, and then to reverse for the other half, and begin again from the notch first cut, which mode of operation requires not only the ends of the rack, but the surfaces also, to be reversed, after the first half of the work is performed.

On the plate of this engine there are thirty divided circles, with the points of division drilled quite through; numbered thus; 365, 360, 144, 100, 60, 30, 96, 90, 80, 78, 72, 54, 48, 62, 94, 92, 64, 59, 86, 88, 84, 82, 76, 74, 70, 68, 58, 56, 52, and 49, which divisions include all the usual numbers introduced in the wheels of clock-work; and such as are not found here may be obtained by the help of the micrometer, when wanted for planetary motions, or other extraordinary purposes.

Cutting Engine by Rehe.

Plate IV. of Engines exhibits a general perspective view of the engine for cutting the teeth of wheels, as originally made by Rehe for his own use, and which, we have said before, is now the property of Mr. Troughton of Fleet-street. It is drawn to one-fourth of the real size. AABCDE is one solid mass of cast-iron, formed into a frame in the mould, of which AA is the upper horizontal part, B and C the ends of the said frame, and DE its base, fixed with four strong screws (the heads of which are visible) to a wooden frame, to which the large wheel is appended, that gives motion to the revolving cutter and some intermediate pulleys placed over the head to give a due direction to the moving cord: this large wheel and these pulleys are purposely omitted in the drawing to give room for the engine itself to be taken on a good scale. F and G are a pair of cheeks forming a part of HI, which is another piece of cast-iron of the shape of a parallelogram, having an oblong aperture through the greatest part of its length, along the middle. KL is the platform, or large plate, of the engine, in which are drilled the dividing holes of a variety of circles; its diameter is nineteen inches; the arbor of this plate is a strong brass tube, MN, resting in a hole on the base, DE, of the large frame, and having a screw formed on its circumference at N, with a corresponding tapped nut, that has got a handle to turn it by; it has also a slit cut through it to admit a wedge under the nut, as may be seen without further description; the upper part of the arbor is supported by a hole in the top part of the frame A A, and passes freely through the oblong aperture of HI. The tubed arbor, MN, of the large plate will receive a variety of arbors successively, each of which has a slit to receive the wedge already named, near N, while the nut N, turned firmly down on the wedge, sets the interior arbor, that carries the wheel to be cut, fast at the shoulder O, on below its superior end. The interior arbor is, however, composed of two pieces, of which the upper part bears the wheel and is screwed fast into the lower part between M and O. There is a great variety of the upper parts of the interior arbor to suit different central holes of different wheels, as well as different shoulders, or resting places, for the wheels to lie upon in a steady manner, all which

would take several plates to represent, but may be easily conceived to be only different sizes and shapes of the same thing; it may, notwithstanding, be right just to remark, respecting these bearing pieces of the arbor, that the centering of the wheel does not depend on the screw part that enters the concealed arbor, but on a circular bed, M, made at the top of the lower half of the arbor, which a corresponding circular piece of metal of the upper half, under the bearing shoulder that holds the wheel, near O, exactly fits, by which means the wheel is certain to be placed in the centre of the large plate, which is an essential condition. The wheel, which is seen with a few notches cut, is fastened by a collet pressed down on its plane, by a tapped nut screwed from above the arbor. P Q is a brass frame, embracing the solid cheeks G and F, and bearing the cutter and its arbor R, that has got a pulley on its posterior end, round which the cord of the first mover goes, and to which it gives the motion at first produced by the foot; when the cutter is taken out to be changed, the end piece S, and a circular piece concealed at the opposite pivot of the cutter arbor, are set at liberty, by the tightening screws, T and T, being turned back *pro tempore*; a plan and side view of one of the cutters, of which there is a great variety of sizes and shapes, may be seen in *fig. 2*, of *Plate VI.*, and the arbor dismounted and separated into its parts in *fig. 5*, of *Plate V.*, of one half its real size, both which may be understood by inspection of the figures, in the latter of which *a* is the pulley on the end of the arbor, *b* the part where the cutter is fixed by pressure of the tubed part *e*, urged by the nut *f*, when screwed home. When the hand U, in *Plate IV.*, is turned, which has a pinion on its arbor taking into a straight rack, fixed to the part embracing the cheek C, out of sight, the whole brass frame has a motion, up or down, as the handle may direct, which is always given it in the operation of cutting each notch. This motion of the whole cutter frame is made easy and smooth by eight sectoral pieces of hard polished steel acting as friction wheels against parallel bars, attached to the cheeks, both within and without the said cheeks; of these sectoral pieces 1, 2, 3, and 4 are seen, but the others, placed in their opposite and corresponding places, are concealed from the view, by the intervening parts of the mechanism. Behind Q, on the posterior part of the cutter frame, is a box containing a spring, with a chain fixed at its lower end to a piece of metal, not seen, between the cheeks and behind the cutter frame, which spring balances the weight of the frame in any position, and renders the working pleasant. Near the character 3 is a perpendicular screw seen, the lower end of which bears against a solid piece fixed between the cheeks, when the frame is lowered so much that the cutter is free from the wheel it is cutting; which screw is also the part of adjustment for the exact depth of a space in a contrate wheel, while the barrel and chain limit the ascent. The whole of this cutter frame is attached to the horizontal parallelogram H I, and is moved to or from the wheel to be cut, by a horizontal screw on the arbor of handle V, which enters a tapped part of the metal under the cutter frame, and when the due distance for making the teeth of a proper depth is ascertained, the whole of the moveable part of the engine is fixed fast in its given position, by the clamping piece W, and crossed nut, that takes the screw on the upper end of a bolt, passing up from below the top, A A, of the large fixed frame; the clamping piece, W, has a dove-tailed projection under it, that enters and fills the breadth of the oblong aperture of H I, and

keeps the piece at right angles thereto. X is the fixing index, or index-bar with a fixing point, that holds the large plate in a given position: this index-bar slides into an octagonal socket Y, to which it is firmly fixed, when necessary, by the thumb-screw seen under it; and near Y is a micrometer head divided into 30 divisions, for which a pin behind it forms an index; by means of this micrometer screw the fixing index can be made to protrude, or retire, any given small quantity, and when its fixing point rests in one of the drilled holes of the large plate, it consequently takes the plate along with it, and also the wheel fixed at the top of the plate's solid arbor. The socket Y has another octagonal hole at right angles to the former one, which enables it to slide along the octagonal axis Z, so that the fixing point of X may approach to or recede from the centre of the plate, and be made to fall into any given divided circle; the numbers of each circle are laid down on the small oblong plate *a*, for which a line on the moving socket, Y, forms an index. This part of the apparatus belonging to the plate would have been sufficient, if the operator were to take the trouble of counting the holes of division on the plate as he turns it in the act of cutting; but in those cases where every second, third, or fourth, &c. hole only is taken by the fixing point, in order to cut a wheel into one half, one third, one fourth, &c. part of the number laid down in any circle, such counting is very troublesome; therefore a curious addition of a moving index *b*, *c* is introduced to be a substitute for the counting. This index turns on the arbor of the large plate, and has a sliding point and thumb-screw *e*, to fix it in any given hole of the circle chosen for the fixing point of X to rest in: *d e* is a sliding stop, passing through a cock fixed to the part, A A, of the principal frame, and is held in any given situation by the thumb-screw over it; and *f g* is another stop attached to a second cock, fixed in like manner to A A; which second stop can be placed in various positions, by means of its own slit and two thumb-screws, and also of the two slits in the cock at right angles to the length of the stop. The use of the moving index is this; when the fixing point of X is fast in its proper hole of any given circle, the moving index is brought so near to it, that its point will fall into the next contiguous, or second next hole, in which situation the inner stop, *d e*, is brought to bear against it and fixed, then the moving index, *b c*, is removed back over two, three, four, or as many holes as are to be counted at each act of cutting a notch of the wheel, from the index X, and is put into the hole so counted, in which situation the outer stop, *f g*, is brought to bear against it and made fast; now it is easy to conceive, that if one hand were to raise the fixing index, X, out of its hole, whilst the other hand were to bring the moving index together with the large plate into which it is inserted, until it meets with the inner stop *d e*, the point of X would then cover the hole counted, into which it might be permitted to fall at random, and it would find its own proper hole under it; then raising the moving index from its hole, and moving it to the outer stop, would place it over the hole to be next counted, into which it might also fall at random. Thus the operation might be repeated all round any given circle, while the stops would act as counters, and the moving index as a handle to move the plate by; but this mode of using the indices would occupy both the hands of the operator, and would require a second person to turn the handle U, and to attend to the cutter; an appendage therefore to the moving index is added, which connects

the moving with the fixing index in such a way, that one hand is competent to manage the whole operation even without the eye being directed to the part, after the stops are properly set, and the indices adjusted; thus, at the part *b* of the moving index is a milled head, like a thumb-screw in appearance, placed on the perpendicular small rod *b*, that passes through this index freely, and attached to a lever *i*, that is moveable on a pin or centre of motion, at the inferior end of the cock *k*, placed fast to the moving index; this lever, *i*, passes on, beyond its centre of motion, till it meets with a long lever under the plate, lying in the direction of the dotted lines passing by *K* on the plate; this second or long lever is fast to the octagonal axis of socket *Y*, which, it has been said, is also the axis of motion of the fixing index *X*; it is easy then to see, that, when lever *i* lies under the lever of the axis *Z*, pushing down the milled head, *b*, over the moving index, will raise the fixing index out of its hole, on the large plate, and set the plate at liberty to move; and also when the said milled head, *b*, is quitted, the fixing index will fall again into the hole that may happen to be under it, and will be kept close by the screw *l*, pressing the long lever down by the intervention of the pin *m*, at its extreme end; all therefore that is necessary to be observed in moving the plate, after the indices and stops are properly adjusted, is, to press with the thumb of the left hand on the nut *b*, before the moving index is carried forwards with the plate, and to let it go before the said index is made to return without the plate, for an attention to this particular raises and lowers the fixing index alternately in the way, and at the times required. When however a wheel is required to be cut into a number of teeth, not to be obtained from one of the divided circles alone, another operation becomes necessary, to take or give a tooth or teeth to complete the number desired; this is done by the micrometer head of the socket, *Y*, of the fixing index, which will push the index out, or draw it in, any small assignable quantity, and will consequently push on or draw back the whole plate a corresponding quantity, provided the micrometer be turned when the fixing point of *X* is in its hole of the divided circle that is used; when this operation is necessary at the cutting of every tooth, the moving index does not fall into a hole, but gradually advances to, or recedes from, its original situation, till it arrives at the next contiguous hole, when one tooth only is to be added or subtracted; but when more than one are required to complete the required number of teeth, the point of the moving index will gradually pass over as many divided spaces of the plate, from its original situation, as there are teeth required to be added or subtracted; so that, if four teeth are to be gained or lost by means of the micrometer, the moving point will traverse one divided space of the plate during the cutting of each quarter of the wheel, and in the same proportion for any other number to be taken or given; whence, at any period, during the act of cutting a wheel into a number not inserted on the plate, it may be seen by inspection of the moving point, at what rate the gain or loss is proceeding upon, which indication forms a good check upon the original calculation by which the micrometer is guided. This advantage, arising from the point of the moving index having a progress or regress over the supplementary divisions, is the more desirable in this engine; because, the fixing index which ought to be always a tangent to the divided circle used, and to have its point at a right angle to the central arbor of the plate, does not preserve the latter condition rigidly, when pushed out or drawn in; which deviation renders the reading of the micrometer in practice, less accurate than

the theory supposes; an objection from which the more complex mechanism of Hindley's engine is free. When a wheel of 142 teeth was cut on our present engine, in our presence, from a divided circle of 140, nineteen turns of the micrometer were found equal to a motion of two divided spaces, as compared with the moving point, when left stationary against the outer stop: therefore, as there are 30 divisions on the micrometer head at *Y*; 19×30 , or 570, were the whole divisions to be divided by the number 142, and gave a quotient of 4, with a remainder of $\frac{2}{142}$; consequently, after every moving of the plate for a new cutting, four divisions of the micrometer head were turned in a backward direction, to lessen the size of the teeth, and to increase their number in the proportion 142 : 140; but at two opposite points of the wheel, the remaining two were interpolated, by giving five divisions instead of four at each place; the additional division on the micrometer, however, made at each of the said two places, made no sensible difference in the size of those teeth, nor would it have been of any importance, if the remainder, which was so small, had been neglected altogether. A similar process, as explained more fully in our account of Hindley's engine, must be adopted agreeably to a similar calculation, for any other number of teeth to be taken in or left out by the aid of the micrometer. The original circles of the large plate were divided by Troughton's dividing-engine into the following numbers, viz. 720, 580, 504, 396, 365, 364, 300, 276, 228, 192, 186, 170, 162, 156, 140, 128, and 118; to which have been since added, at different times, the numbers 274, 260, 206, 148, 136, 130, 111, 103, 101, 87, 83, 74, 65, 47, 43, 41, and 37, so that, by this engine, all numbers under 100 can be cut without the help of the micrometer, except 97, 95, 89, 88, 79, 77, 61, 53, and 49.

When our present engine is used to cut pinions on their arbors, a steel perpendicular bar descends from a beam in the room directly over the centre of the plate, and holds the upper end of the arbor steady, while the lower end is made fast to the revolving arbor. There are also many other useful appendages to the engine, some of which merit a particular description and corresponding drawings, which we have obtained.

Fig. 1, of Plate V. is a detached cutter frame of one-fourth of the real size, to be used occasionally when a wheel is wanted to act with a worm-screw, in which case the teeth are required to be a little inclined from the axis to the right or left, accordingly as the screw is a right or left-handed screw. When this cutter frame is used, it is attached to the cheeks *G*, *F*, in Plate IV., without disturbing the frame already attached. *A* *B* is a strong brass plate with two forked pieces, *C*, *D*, projecting back from its posterior plane near the top; these forks enter over the sliding frame *S* *Q*, in Plate IV., and embrace the two tapped studs *n* and *p* not seen, within the cheek, by which they are held fast when pressed by the tapped nuts of the said studs; at *A*, the bottom of the plate *A* *B*, in fig. 1, of Plate V., is a screw which enters the small tapped hole, near *I*, on the sliding piece *H* *I*, in Plate IV., and a corresponding screw at the other side, out of sight, holds the fourth or concealed corner of the said plate *A* *B*, so that this plate, when thus attached, may be considered as a part of *H* *I*, in Plate IV., behind which additional plate the common cutter frame is concealed, and remains useless for the time. *E* *F* is a second plate of brass of nearly a semicircular shape and graduated on its periphery; this second plate is attached to the former one, *A* *B*, by two tapped bolts passing through the long opening *G*, and made fast with nuts at *E* and *F*, by which

means this second plate can be placed at any given height on A B, and a motion, which it has round E, as a centre, allows of its being placed to any angle of obliquity marked on its periphery; the circular slit at E, allowing the upper or fixing bolt to pass along it to any required position, before it is fixed by the nut: the cutter frame, H I K L, moves on pivots in the feet of E F, near A and K, which pivots are turned out of an horizontal line to the right or left, by the obliquity given to the plate E F, and consequently the cutter arbor, L I, has also an obliquity, which makes the cutter at the middle of it cut the notches in an oblique direction; this cutter, however, having but one centre of motion, or rather one pair of centres, cuts the bottom of the notches of a wheel in a circular direction. The arbor of the cutter has a pulley which gives it motion, and the two pulleys, *a* and *b*, over it have no other use, but to direct the cord to the larger distant pulleys, not shewn in the drawing. When the plate, E F, is adjusted to zero, or horizontal line, it may be used for cutting ordinary wheels, but is liable to be displaced by accident or jerks in cutting; therefore is used only for wheels with oblique teeth. The French engine recommended by Berthoud, as made by Hugot has, notwithstanding, no other cutter frame but that which is adjustable for obliquity. The vertical screw, *d*, is a rest for limiting the depth of the spaces of contrate wheels in cutting, and also for stopping the descent of the frame further than is necessary in cutting other wheels: the opening B of the plate A B seems to have no other use, except for the eye to look through at the cutter, when the workman stands behind the cheeks to turn the first moving wheel of the cord, which wheel, we remarked, is not very conveniently placed to consult the easy position of the body, during the act of cutting. This frame being attached to the sliding part H I, of *Plate IV.*, is of course capable of the adjustment for distance from the arbor of the plate, on which the wheel is placed, that requires to be cut.

Fig. 2, of Plate V. is a representation of the apparatus for cutting the interior edge of an annular wheel, such as is used in a theodolite, and solar microscope, &c. of $\frac{1}{4}$ of the actual size. A B is the ring or annular wheel to be cut, which is fixed to the top of the arbor by means of the wooden chuck, on which it was turned in the lathe, and *a b c d* is a short frame for the cutter, and cutter-arbor, seen detached in two pieces in *fig. 3* of $\frac{1}{4}$ the real size. This small frame is attached to the face of the cutter frame in *Plate IV.*; its arbor, *a b*, enters the hole of the arbor at S, and an opposite hole not seen in *Plate IV.*, after the arbor, R, has been previously removed, and is made fast by the two screws *x* and *x*, entering the holes *c* and *d*, of *fig. 2. Plate V.*; the interior teeth are then formed by the small cutter, by a process similar to that of cutting the exterior teeth of a wheel in the ordinary way.

Fig. 4, of Plate V. is a contrivance of $\frac{1}{4}$ of the real size, for cutting a rack into any number of teeth per inch, by the aid of the engine plate and common cutters, thus; A and B are two strong cocks screwed fast to the opposite sides of H I, already described in *Plate IV.*; C is a piece of metal forming a bed for the oblong bar, D E, to rest on; this bar, which is a rack already cut, is placed with its teeth in action with a wheel of 74 teeth nicely rounded, that is attached to the arbor of the plate in the usual way; under the bar D E, and fast to it, is a rib parallel to its sides, moving easy in a corresponding long groove made in the bed, C, to receive it, the motion of which is made smooth by friction wheels interposed and borne by the bed;

the bar, D E, has a great number of holes drilled and tapped in it, that the moveable corks or clamping pieces, F, F, and F, may fix any bar, G, to be cut into the requisite rack; when the mechanism is thus arranged and properly fixed, the motion of the wheel, caused by moving the subjacent plate, a given number of holes of any circle fixed on, will carry the racked bar D E, and bar G along with it, over the bed a certain distance, between the cutting of each space of bar G, and this distance may be made $\frac{1}{10}$ th, $\frac{1}{12}$ th, or $\frac{1}{16}$ th of an inch, according to the number of divided holes on the plate, passed over by the moving index, between each operation of cutting.

These three appendages render the engine competent to cut teeth in all ways, and on all wheels and bars that are in use in mechanical contrivances; but the teeth thus formed with ordinary cutters, are in the shape of parallelograms, and require to be rounded by hand with a file or files of different coarseness and shape; the contriver, in common with other workmen, had experienced the inconvenience attending the finishing, both as it was a laborious operation, and liable to produce irregularities in the shape of the tooth, on which the equable transmission of power and velocity entirely depend, in clocks, watches, and other delicate machines; he therefore constructed his cutters in such a way, that they rounded the teeth at the same time that they cut the spaces; this invention is very important to the successful application of racks and wheel-work in many cases, where a good shape of the tooth is indispensable, and has been claimed by both Rehe and the late ingenious Merlin; but which of the two, if either, was the real inventor, remains to be decided.

Plate VI. of Engines, contains the drawings of some cutters to answer the purpose of rounding the teeth during the act of cutting, and also the apparatus for forming the cutting edges and for sharpening them when blunt, which apparatus is indispensably necessary to accompany the engine when *finishing cutters*, as we shall henceforth call them, are adopted in practice.

A A, in *fig. 1*, is the front side of a wooden bench, to which a foot wheel, as a first mover, is fixed out of the drawing, and B B is a small frame attached to its inferior plane; C C C is a species of small lathe, with a three-grooved pulley revolving on a solid arbor, together with the arbor itself; this lathe is attached to the brass plate D D, and by means of it screwed fast to the wooden bench A A; at the exterior end of the arbor that bears the pulley, is fixed a circular copper plate, E, with its plane at right angles to the said arbor, which plate consequently revolves with the pulley, when the foot wheel gives motion to the cord that embraces it: just above the brass plate, D D, of the small lathe, lies parallel thereto another stronger but smaller plate, F F, attached to and borne by a side plate, G G G G, that fits the frame under the bench, and slides up or down to nearly the height required in use, in which it is fixed by the thumb screw at H, under the bench; at the ends of the plate F F, which we will call the bed of the cutter frame, or frame for holding the cutter while grinding, are two cross bearing pieces near F and F respectively, on each of which are cut three semi-circular notches, some of which are seen at *a*, *a*, and *a*; I I is the horizontal plate of a cutter frame resting on the horizontal tapped wire, K, that has got a milled nut screwing upon the tapped part beyond the bed F F, and has its opposite bearing end concealed under the other parts; this plate, I I, may be fixed to any part of the bearing wire, K, by the thumb screw *b*, and will have a little circular motion round the wire, to the right or left, when not held in the

hand, or nicely balanced; above this plate, I I, lies a still smaller plate, L, that bears the cock M, and another similar one concealed, but opposite to it; which small plate, L, is moveable round a centre of motion under it, on the next subjacent plate I I, but can be fixed in any given position by the thumb screw at L, agreeably to the graduations marked near its extreme end, beyond the circular groove penetrated by the thumb-screw, for which graduations a line on the small cock, d, constitutes an index: into the cock M, and the one concealed, passes an arbor not seen, that may be called e, which is capable of being fixed by pressing screws at the exterior sides of the said cocks; across this arbor, e, at right angles, is a long hole, or tube, into which the cutter arbor is inserted, and fixed by a pressing screw N; so that the plane of the cutter may be made either horizontally parallel to the copper circle E, or to stand in an inclined direction: accordingly as the arbor, e, is turned more or less round before it is fixed by its pressing screws at M, and at the opposite pivot; while the thumb screw at L, by the help of the graduations near it, fixes the planes of the cutter and circular plate, E, vertically parallel, or at any given angle of reclination to each other, as the shape of the acting faces of the tooth may require; the nut at D limits the proximity of the cutter to the circle E. In the present position of the cutter, its plane is smoothed by emery smeared over the copper circle, as the arbor revolves, and while the plate, I I, has a circular motion given it backwards and forwards by hand, round the bearing wire K, which alternate motion carries the cutter across the plane of the grinding circle E, and assists the grinding; upon the arbor e, not seen, is a second divided scale of a circular shape, like a micrometer head, by means of which the situation of this arbor, and consequently of the cutter's plane, is adjusted before the pressing screws are made quite fast; and a small gauge, near f, like a small leg and foot, moveable at its knee, on the cock, presents its heel to a tooth of the cutter, and limits its position in such a way, that each succeeding tooth to be sharpened may be fixed, by the pressing screws, in precisely the same situation while they are respectively sharpened. By the help of these various adjustments of the plane of a cutter, such, for instance, as is seen in two views in *fig. 2*, the preceding or cutting part of each tooth is made thicker than the following part, and also the part at the periphery thicker than the part nearer to the centre, which shape makes the cutter clear itself in the space it cuts as it advances, a condition that experience has proved to be necessary in forming or sharpening a cutter. When one plane of each tooth of a cutter has been gone round, the planes are reversed, and the cutter fixed as before by the help of the scales, gauge, and screws, and then the former process of grinding the teeth singly in succession is repeated.

When the plate I I, with its appendage, which together we have called the cutter frame, is lifted out of the semicircular notches or bearings on the ends of the bed F F, and is laid aside; another nearly similar frame, seen in *fig. 3*, is put into its place, with the parallel wires, a, a, and a, resting in the said semicircular notches, as in *fig. 1*, are denoted by the same characters; in this situation the nut, D, in *fig. 3*, falls in the place of nut D in *fig. 1*, and answers the same purpose of adjustment for proximity of the cutter to the grinding circle E; the small upper plate, L, is also nearly the same as in *fig. 1*, both as to its position and uses, where also the index line of the small cock, d, points out the degree of obliquity on the graduated sectoral part; but here the frame is not a single plate I I, resting on the

bed as in *fig. 1*, but has a motion round the pivots h and h, placed on another plate that bears the wires a, a, and a, so that the two plates may be made to open, and form a blunt wedge, by turning the screw k, which bears on the lower plate with its point, and is tapped into the upper plate, after which adjustment for height, which cannot be made nicely by sliding G G G only, the position is rendered permanent by the fixing nut, l, that takes a tapped stud fixed to the lower plate. In this figure, the arbor that holds the cutter is in the situation of the arbor e, *fig. 1*, which we said cannot be seen; and the ends of the teeth are presented to the grinding face of E, which position of the cutter could not be attained by the mechanism of *fig. 1*. On the cocks that bear the pivots of the cutter arbor, are fixed two small cannons, on which the bent arms, m and m, revolve, and are fixed by the pressing screws n and n; the play of the arbor is limited by the two thumb-screws o and o, fixing the stops in their respective places; and a wire, k, connected with the arms m and m, forms the centre of motion of the leg or gauge, which is here better seen than in *fig. 1*, and performs a similar office. It is hardly necessary to add, that after each tooth is pointed in this way, the fixing screws m and m, and also the gauge f, are released for the moment, and brought back again to their original situation at the adjustment of every successive tooth to the grinder.

For sharpening the front edge of a tooth, the cutter must be reversed, the bed lowered, and the nut, D, turned back, till the position, represented in *fig. 4*, be obtained; in which the teeth are successively ground as before directed.

The mechanism above described is all that would be necessary, if the tooth of the cutter were made by straight lines to cut teeth of a shape like a parallelogram, but to round them at the same time required another addition, which remains to be described.

In *fig. 5*, are seen two different views of a cutter, such as will round the teeth and cut them at the same operation, by means of the sides of the cutter's teeth being formed into curves; these curves ought to be epicycloids, or involutes of a circle to constitute a tooth of any wheel of the exact shape requisite for the equable transmission of power and velocity, and these curves should vary in shape with the size of the wheel compared with its pinion or fellow-wheel; but such niceties cannot be obtained in practice without almost infinite trouble; therefore the same cutter, once shaped and sharpened, is used for wheels of different diameters, where its thickness is found proper. *Fig. 6*, shews how the side curves of the cutter's teeth are formed, where a cylinder of copper is substituted in the small lathe C C C, *fig. 1*, for the arbor and circular plate E; *fig. 3*, is then applied to the bed F F, and the side of the tooth is adjusted to touch the side of the cylinder as it revolves; this mode of application would make the curve circular if the cutter-arbor were to stand at right angles with the grinding cylinder; but as any degree of obliquity can be given, by undoing the thumb-screw b, and moving L, the position ought to be such as to make the tooth rest obliquely against the cylinder, more or less, as the shape may require, in which case an elliptic curve, instead of a circular one, is formed on the edge of the cutter, by reason of the oblique section of a cylinder forming an ellipse, which curve approximates nearly to the shape required in a given degree of obliquity, and may always be used when once determined. When the curves on one side of each tooth of the cutter are thus formed, which are assisted by a motion lengthwise of the frame in the bed, while the wires a, a, and a, slide in their bearing notches, the planes of the

CUTTING ENGINE

cutter are reversed and the opposite corresponding curves are formed in a similar manner. Cutters of this kind not only facilitate the labour of making wheels, but render them more perfect than manual filing can possibly do; and it is to be regretted that clockmakers in general will not

go to the additional expence of having them thus formed. Thus, each of the two engines we have described, have appropriate advantages; and we think it would not be difficult to construct one that would unite the advantages of both, and be preferable to either.

Cutting Engine by Hindley.

Fig. 2.

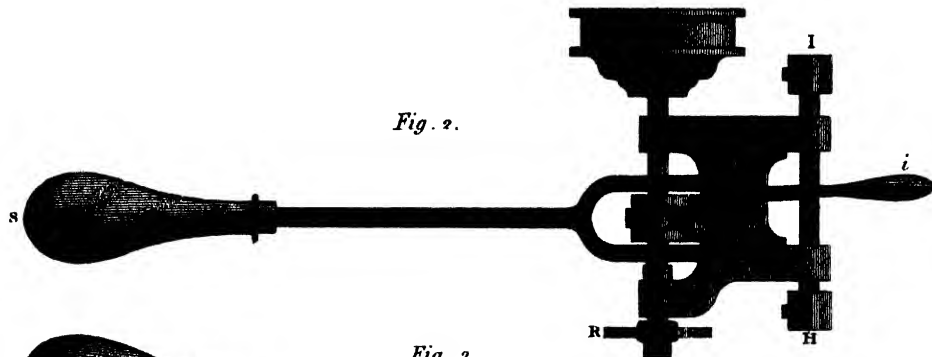


Fig. 3.

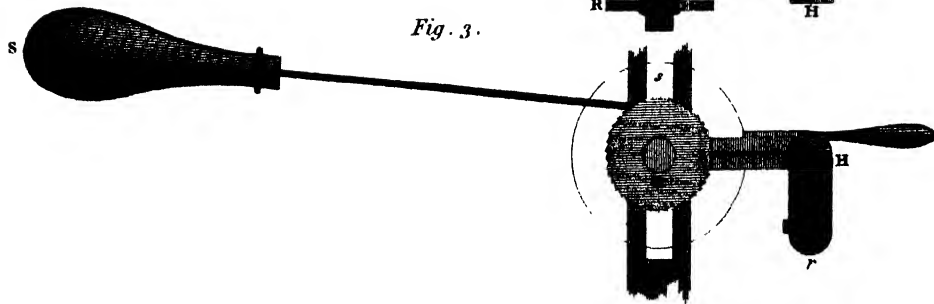
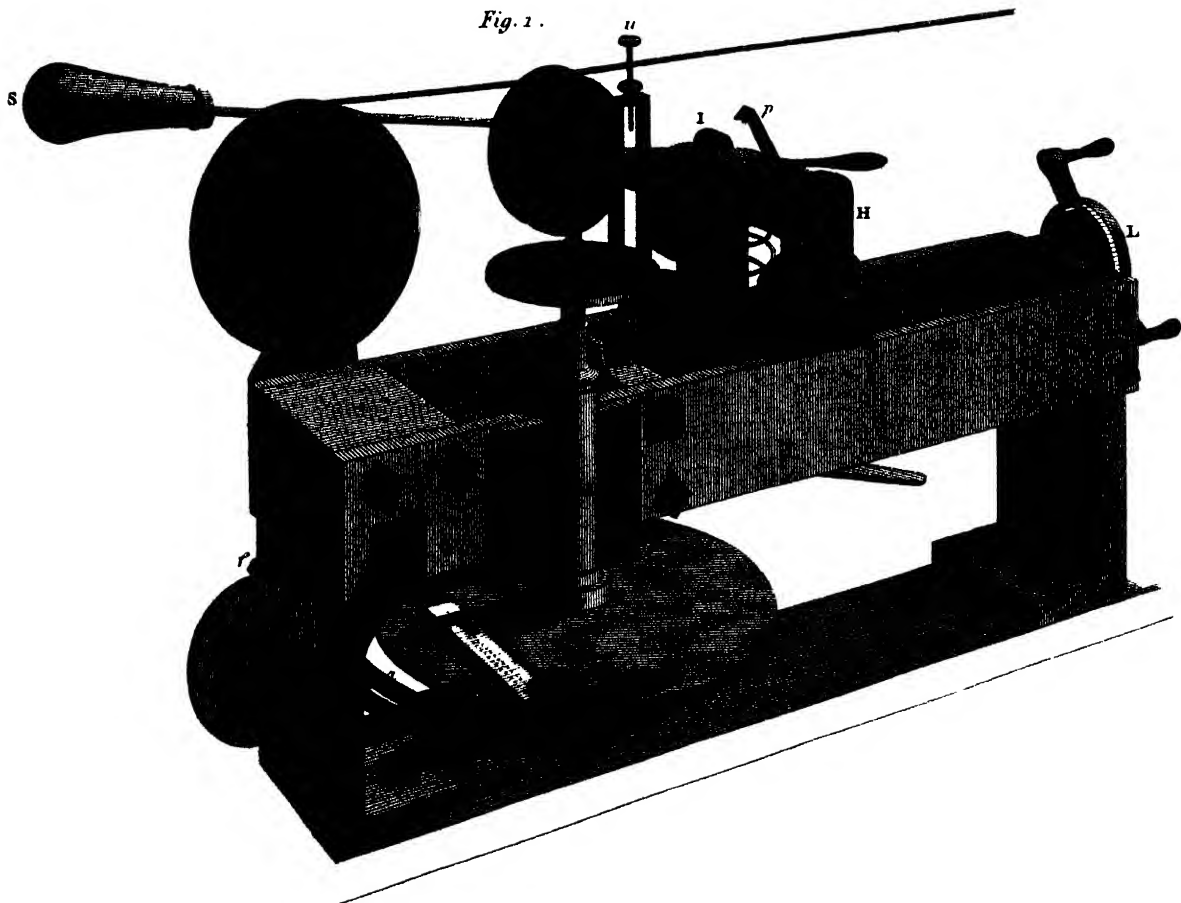


Fig. 1.



ENGINES. CUTTING ENGINE

PLATE

Fig. 2.

Fig. 4.

Fig. 5.

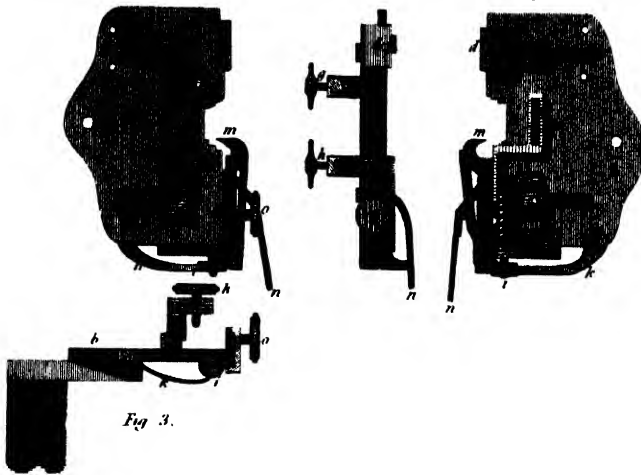
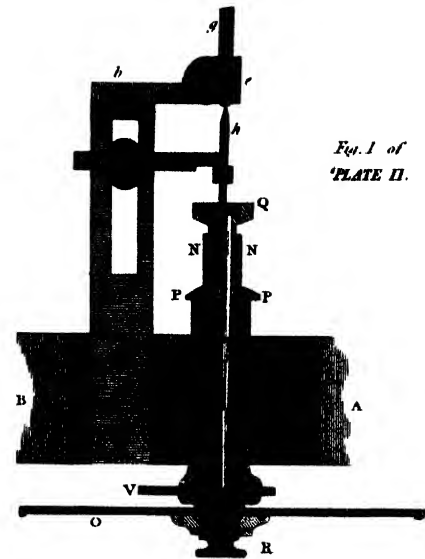
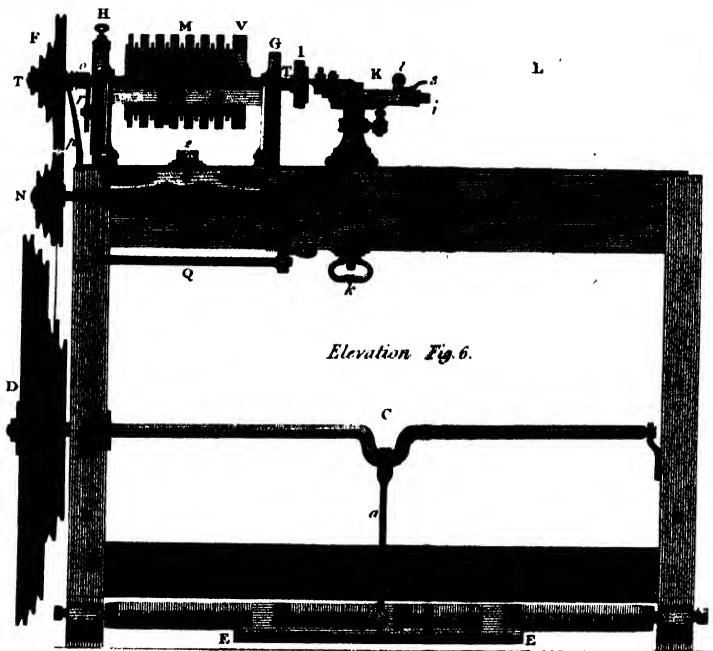


Fig. 1 of
'PLATE II.



Base Engine or figure Lathe made by Mess^{rs}

Holtzapffell & Degerlien.



Elevation Fig. 6.

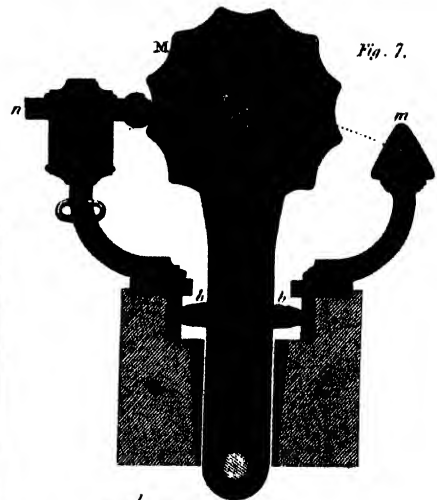


Fig. 7.

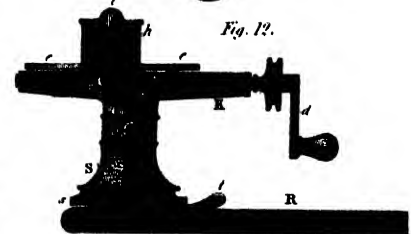


Fig. 12.

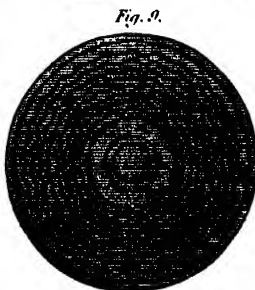


Fig. 9.

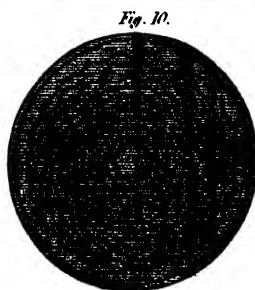


Fig. 10.



Fig. 10.

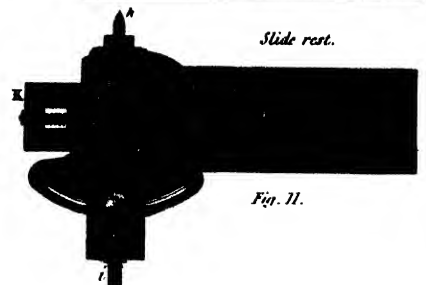


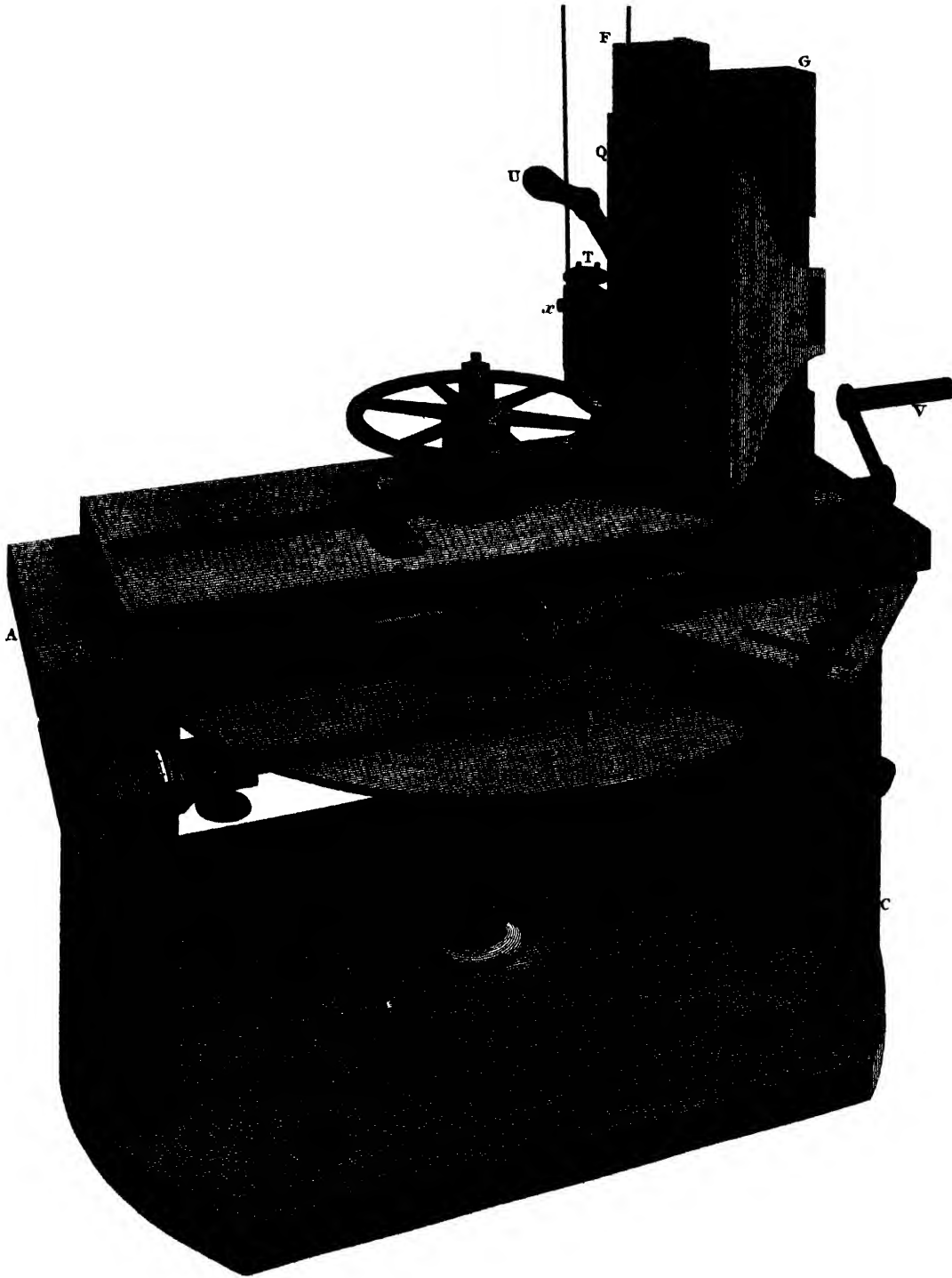
Fig. 11.

Slide rest.

ENGINES.

PLATE IV.

cutting ENGINE by Rehi.



ENGINES.

PLATE

CUTTING ENGINE by REHE.

Fig. 3.

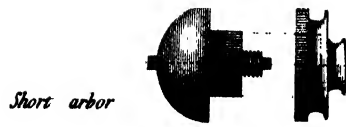
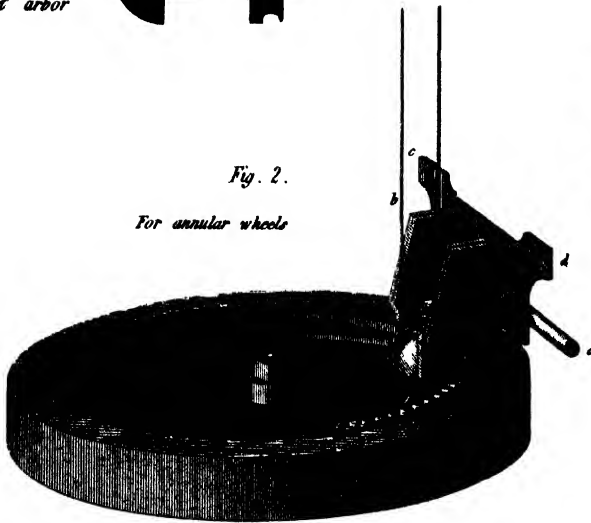


Fig. 2.

For annular wheels



For worm wheels

Fig. 1.

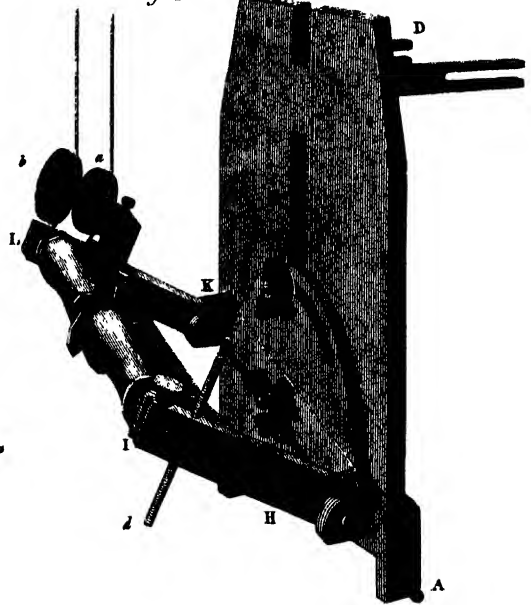


Fig. 4.

1866. Taken on the axes of the machine

For Racks

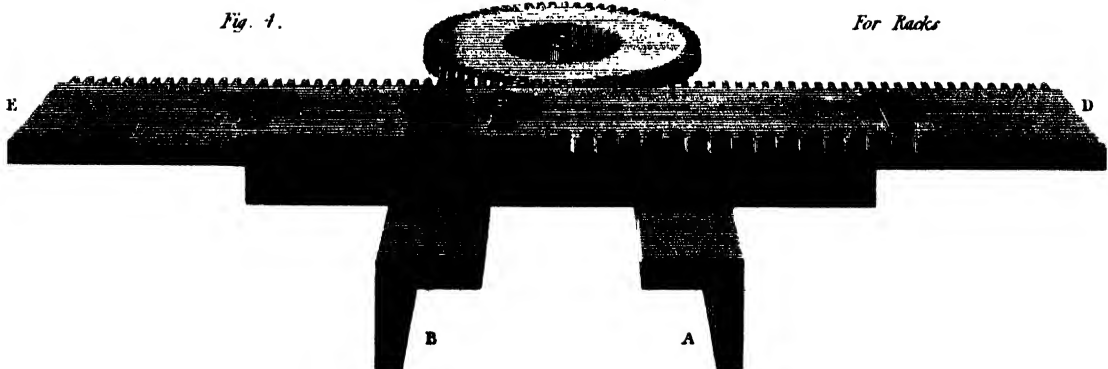


Fig. 5.



ENGINES.

For sharpening Cutters.
BY REHE.

PLATE VI.

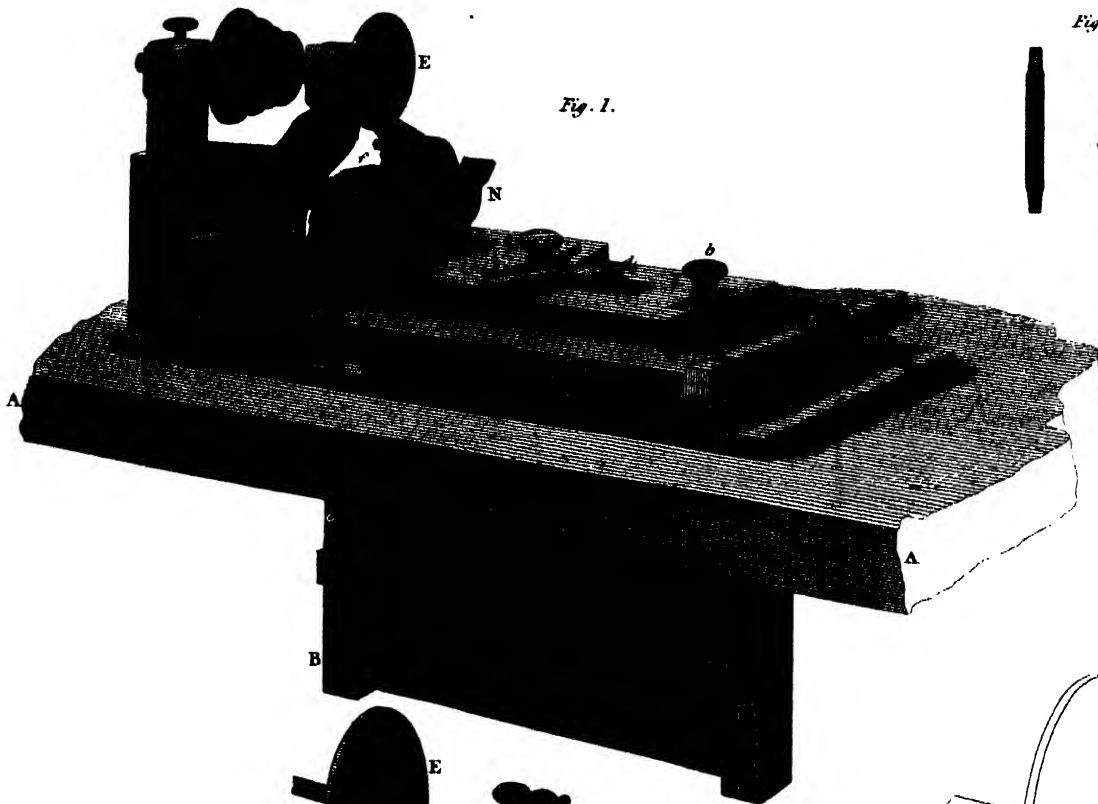


Fig. 1.

Fig. 2.

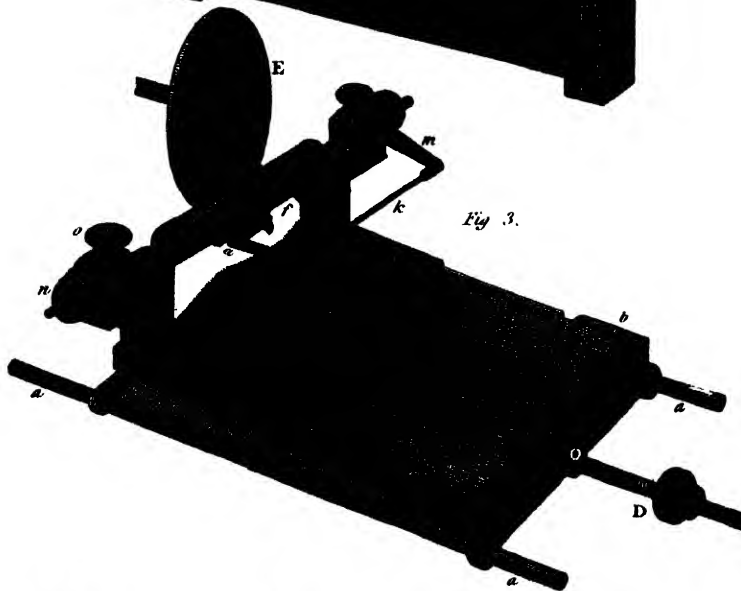


Fig. 3.

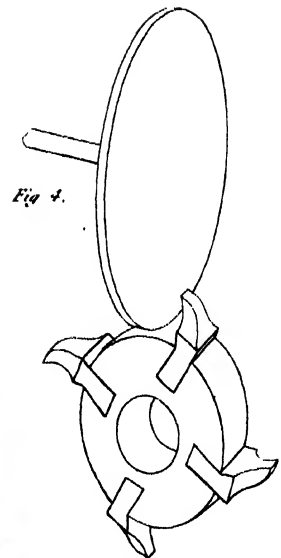


Fig. 4.

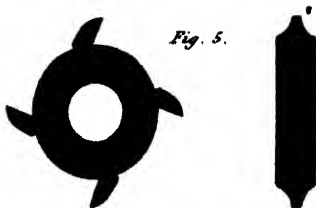


Fig. 5.

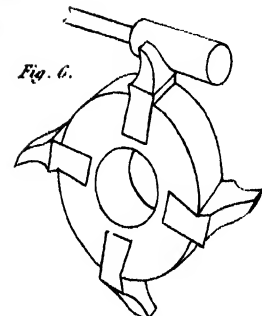


Fig. 6.

Cyder

CYDER, in *Rural Economy*, is a fruit liquor prepared by means of fermentation, from the expressed juice of different sorts of apples. The process by which this liquor is formed has much similarity in all the different districts where it constitutes an object of the farmer, though there is much diversity in regard to the care and management which are bestowed upon it.

The varieties of apples which are grown and cultivated in the various fruit districts of the kingdom, with this intention, are extremely numerous; but by some it is supposed

that all such as have a yellow or light red ground, are tinged with red streaks on the sun side, having a smart acid flavour, with a firm juicy parenchyma and an aromatic flavour, whatever the name may be, are unquestionably proper for cyder. It has, however, been remarked by Mr. Knight, that the properties which are essential for cyder and the table are rarely met with in the same fruit. That degree of firmness which is necessary in the eating apple, is useless in the cyder fruit; and colour, which is disregarded in the former, is amongst the most important qualities of the latter. Some degree of astringency, which is prejudicial in the eating

fruit, is conceived beneficial in that made use of for cyder. In Devonshire, according to Mr. Vancouver's Survey, a rich sweet fruit is generally preferred for the purpose of cyder, while in others those which have more astringency are held in the highest estimation. See APPLE, APPLE-TREE and ORCHARD.

Gathering the Fruit.—In the business of gathering the fruit for this liquor, much care should be taken that it be sufficiently ripe before it is removed from the trees, otherwise the cyder will be harsh, rough, and unpleasant in its taste, in spite of any thing that can be done in the process of making it. The most certain indications of ripeness, according to Mr. Crocker, are the fragrance of the smell, and the dropping of the apples from the trees in a spontaneous manner.

The most early ripe fruits should, of course, be first gathered, but as on the same trees the fruits rarely become equally ripe at the same period of time, it is found necessary to throw them together into large round heaps in the open air, as noticed below, in which state they are suffered to continue for some time, until a sort of sweating or fermentation has been brought on, which induces a similar state of mellowness and fitness for grinding in the whole heap. This method, however, which requires much judgment in directing it, does not, even under the most careful management, always answer the purpose; therefore the nearer the apples approach towards perfect ripeness the better, as their juice is the more rich.

Mr. Crocker advises that in a dry day, when the fruit has acquired such a state of maturity as to be ready to drop from the tree, that the limbs or branches of it should be slightly shaken, and disburthened in a partial manner of its apples, thus taking only such as are in a ripe state, leaving the others to acquire a due degree of maturity. It is indeed suggested as proper to make three gatherings of the crop, keeping each of them by itself.

The latter gatherings, as well as the wind-falls, can, however, only be employed in making inferior cyder: the prime cyder must be drawn from the first gatherings which have been made.

According to Mr. Knight, the merit of cyder will always depend much on the proper mixture, or rather on the proper separation of the fruits. Those whose rinds and pulp are tinged with green, or red without any mixture of yellow, as that colour will disappear in the first stages of fermentation, should be carefully kept apart from such as are yellow, or yellow intermixed with red. The latter kinds, which should remain on the trees till ripe enough to fall without being much shaken, are alone capable of making fine cyder. Each kind should be collected separately, as noticed above, and kept till it becomes perfectly mellow. For this purpose, in the common practice of the country, they are, as stated above, placed in heaps of ten inches or a foot thick, and exposed to the sun and air, and rain; not being over-covered except in very severe frosts. The strength and flavour of the future liquor are however, he says, increased, by keeping the fruit under cover some time before it is ground; but unless a situation can be afforded it, in which it is exposed to a free current of air, and where it can be spread very thin, it is apt to contract an unpleasant smell, which will much affect the cyder produced from it. Few farms are provided with proper buildings for this purpose on a large scale, and the improvement of the liquor will not nearly pay the expence of erecting them. It may reasonably be supposed that much water is absorbed by the fruit in a rainy season; but the quantity of juice yielded by any given quantity of fruit will be found to diminish as

it becomes more mellow; even in very wet weather, provided it be ground when thoroughly dry. The advantages therefore, of covering the fruit, will probably be much less than may at first sight be expected. No criterion appears, the writer says, to be known, by which the most proper point of maturity in the fruit can be ascertained with accuracy; but he has good reason to believe that it improves as long as it continues to acquire a deeper shade of yellow. Each heap should be examined prior to its being ground, and any decayed or green fruit carefully taken away. The expence of this will, he observes, be very small, and will be amply repaid by the excellence of the liquor, and the care with which too great a degree of fermentation may be prevented in the process of making it into cyder.

Mr. Crocker has likewise remarked that the cyderist, who would be particularly curious in his prime liquor, should hand-gather his fruit, and keep the sorts separate one from another: but as this would be troublesome, expensive, and in a full season wholly impracticable, the general crop may, at different times, be shaken down, and collected from the ground. Fruit of equal ripeness, and whose qualities are nearly alike, should be heaped together, to meliorate their juices, or, in other words, to perfect the saccharine fermentation. How this is best done, cyder-makers are not, the writer says, agreed: some, says he, judging it altogether unnecessary to keep them at all, if sufficient time be allowed for perfecting the saccharine fermentation on the tree: some considering it best to sweat them in close lofts, whilst others allege, that the open air is the only place where they ought to be heaped. Experience, however, should, he thinks, teach us that most apples require time for their being mellowed, to attain their highest flavour; and, until thus mellowing be perfected, their juices are not in the best state possible for being converted into cyder-liquor.

However, philosophy has shown, he thinks, that fermentation is never improved by hastening the operation with too much heat; nor perfected in due time under too great an exposure to cold. It would be well, therefore, says he, if apples, when gathered from the tree, were placed in open sheds, having boarded floors, in heaps or layers of ten or twelve inches deep; the hard and harsh fruits might probably, he supposes, be laid in heaps of greater depth; the sorts to be kept separate, as much as the nature and conveniences of the sheds will allow: at any rate there must be a mixture of apples in the same heap; let them, says the writer, be such as are of qualities nearly alike, and which are of equal ripeness at the time of gathering, but on no account should sweet and sour fruit be heaped together. To some cyderists it may, says he, have appeared unnecessary to keep the different sorts of apples separate, but it is of importance so to do: and the trouble is very little, as has been observed, compared to the advantages which will hereafter result from a regular fermentation of the juices. The impropriety of housing and laying apples in very large heaps must, the writer thinks, be manifest to every thinking mind; more especially when in the same room are found all sorts; sweet, sour, harsh, generous, ripe, and unripe, thrown promiscuously together; where some are rotten before others are mellowed. And what must the liquor be, he asks, which is expressed from such an heterogeneous mass?

In respect to heaping, the author of the Survey of Gloucestershire well remarks, that though it may improve unripe fruit, it cannot communicate the richness found in that which is fully ripened. And that the effect which is thus produced on those which are heaped in a very green

and unripe state, is rottenness, in which condition very few are capable of communicating an unpleasant flavour, even to a very large quantity of the liquor, especially where they have become of a black appearance.

Supposing, says Mr. Crocker, that the fruit, which is of different sorts and qualities, has been kept separate from one another a few weeks, it will be perceived that some of the prime sorts are in a proper state of maturation; that the pulp has acquired its highest degree of richness; the kernels assumed their brownest colour; the rind still free from any appearance of rottenness; and that they readily yield to the pressure of the thumb: then is the time, says he, and such is the fruit to be employed in making prime cyder: every necessary utensil must now be set in order: the mill, press, tubs, casks, pails, and bowls, clean washed, and suffered to dry before they are employed in the business.

The able writer of the Agricultural Report of the County of Gloucester very strongly and very justly reprobates the too common practice of those who indiscriminately, and without any regard to the maturity of the fruit "run over the whole orchard with the beating pole, or 'lug' and bring down every apple within their reach," as thus beating the trees before the fruit is nearly ripe is not only injudicious in respect to the cyder, but injurious to the succeeding year's crop of fruit; the bearing buds for the next season being formed early in the summer near, and even attached to, the growing fruits. Of course, the beating of the trees, unless where the apples separate with facility, must of necessity bring off the buds which nature had provided for the ensuing year, with them. And he adds that, "after an operation of this kind the ground is strewed with these buds, to an extent scarcely to be conceived by those who have not witnessed it." The practice of the most careful farmer is therefore, he says, to have the trees "shaken limb by limb, by a person up in the tree," only suffering the few that remain to be beaten off, and occasionally even allowing them more time to ripen, which he considers by far the best practice, except that of suffering them to fall of their own accord, as securing a regular fermentation with less keeping.

Grinding the Apples. In the business of grinding the fruit for this use, into what is termed pommage, several different methods are practised: but those most commonly in use are the bruising-stone, with a circular trough, and the apple-mill. In the first of these methods the apples are thrown into the trough, and bruised by the motion of the stone, as it is moved round by a horse, in the usual way that tanners grind their bark. This is a very ancient method, and which is still in use in some parts of Devonshire; and although it has its inconveniences, in bruising some apples too much and some too little, it is not without its advocates in these parts of the country; the inhabitants of which allege, that it bruises the kernels of the fruit better than other machines. Although it must be admitted, that the kernels possess an agreeable aromatic bitter, yet it has been held questionable if they impart any perceivable beneficial quality to the cyder. Be this as it may, certain it is, that this method of converting apples to pommage by the trough and stone has, in the last fifty years, much given way to the apple-mill.

The author of the treatise on the apple and the pear has remarked that when iron mills have been tried, this metal has been found to be soluble in the acid of apples, to which it communicates a brown colour and an unpleasant taste. No combination has, he believes, been ascertained to take place between this acid and lead; but as the oxyd or calx

of this metal readily dissolves in, and communicates an extremely poisonous quality to, the acetous juice of the apple, it should, he thinks, never be suffered to come into contact with the fruit or liquor. In the construction of these mills, there are various methods had recourse to in regard to their motion or moving powers, some being worked by hand, some by horses, and others by water. The horse and water powers have obviously considerably the advantage in the quantity of work that is capable of being performed; but the hand method is supposed capable of reducing the pulp into a state of greater suaveness, where the latest improvements in mills of this kind have been adopted. See *CYDER-Mill*.

It has been suggested in the Herefordshire report, that each sort of apples should be ground separately, or at least such sorts in mixture as become ripe at the same time; but on the authority of Mr. Appesley of Withington and other manufacturers, it is stated, that the former practice is that by which "fine cyder of different flavours and degrees of strength is obtained, from the same orchard, the liquors being mixed after they are made." It is however allowed that "in all common cases," the practice of grinding different varieties of fruit equally ripe, together, is found eligible; as it is less difficult to find the requisite degrees of richness, astringency, and flavour, in three varieties, than in one. And hence it is supposed that cyders made from the juice of mixed fruits under common management, generally succeed with greater certainty, than those from only one kind. In the grinding, the fruit should be reduced as nearly as possible to an uniform consistence, in such a manner as that the rinds and kernels may be scarcely discernible from the general mass; the operation proceeding slowly, with a free access of air. The quantity of fruit which is usually thrown into the cistern at one time to be ground, is about two bushels in the large mills.

Pressing the ground fruit.—It is remarked by Mr. Crocker, that cyderists are not agreed in opinion, whether the pommage should immediately after grinding be conveyed to the press, there to be formed into a kind of cake, or what is sometimes called the cheese; or whether it should remain some time in that state before pressing. Some say it should be pressed immediately after grinding; others conceive it best to suffer it to remain in the grinding trough, or in vats employed for the purpose, for twenty-four hours, or even two days, that it may acquire not only a redness of colour, but also that it may form an extract with the rind and kernels. Both extremes are, he thinks, wrong. There is an analogy, he supposes, between the making of cyder from apples, and wine from grapes; and the method which the wine-maker pursues ought, he thinks, to be followed by the cyder-maker. When the pulp of the grape has lain some time in the vats, the vintager thrusts his hand into it and takes some from the middle of the mass; and when he perceives by the smell that the luscious sweetness is gone off, and that his nose is affected with a slight piquancy, he immediately carries it to the press, and by a light pressure expresses his prime juice. In like manner should the cyderist determine the time when his pulp should be carried to the press. If he carry it immediately from the mill to the press, he might lose some small advantage, which may be expected from the rind and kernels, and his liquor may be of lower colour than he might wish. If he suffer it to remain too long unpressed, he will find to his cost, that the acetous fermentation will come on before the vinous is perfected; especially in the early part of the cyder-making seasons. He will generally find, he thinks, that his pulp is in a fit state for pressing in about twelve or sixteen hours. If

he must, of necessity, keep it in that state longer, he will find a sensible heat therein, which will engender a premature fermentation; and he must not delay turning it over, thereby to expose the middle of the mals to the influence of the atmosphere. Mr. Knight, however, thinks it should remain twenty-four hours before it is taken to the prefs. And the writer of the "General view of the state of agriculture in the county of Gloucester," states that there the pulp is either immediately carried to the prefs, or, which is better, laid up in tubs or open casks for twenty-four hours; by which the colour is improved, and by the digestion which takes place, a more intimate union of the rind, kernel, and stalk juices are produced, especially when again carried to the mill and reground. See *CYDER-Prefs*.

The ground fruit or pommage being now in a proper state, it is carried to the prefs, and a square cake or cheese made of it, by placing very clean sweet straw or reed between the various layers of pulp or pommage; or by putting the same into hair-cloths spread upon the vat, and placing them one on another. They are turned up on the sides and corners over the pulp, so as to nearly meet in the centres. They are laid very even, ten or twelve being often applied over each other in regular layers, the square frame of the prefs being raised with them, keeping the pile to an uniform size. Upon the whole, a strong board is placed, wider than the pile, on which the blocks of the prefs rest. It is of importance that the straw or reed, where they are used, be sweet and perfectly free from any mustiness, lest the cyder be impregnated therewith. Particular care ought also to be taken to keep the hair-cloths sweet, by frequently washing and drying; or the ill effects of their acidity will be communicated to the cyder. To this cake or cheese, after standing a while, a slight pressure is at first to be given by lowering the screw of the prefs, which must be gradually increased as the cakes become dryer, until all the must or juice is expressed, which is usually completed by the long lever and windlafs: after which, the juice must be strained through a coarse hair sieve, to keep back the gross feculencies of the juice, and be put into proper vessels. These vessels may be either open vats, or close casks; but as in the time of a plentiful crop of apples, a number of open vats may by the cyderist be considered an incumbrance in his cyder-rooms, the must should be generally carried immediately from the prefs to the cask. The pressed pulp or cheeses, as they are termed, on being removed from the prefs and taken out of the cloths, are thrown away, when not designed for further use; but when the crops are scanty they are sometimes laid by in some places, to be afterwards reground with water, from which is afforded a liquor of weak quality, which is denominated in some places *washings*, but of sufficient strength to render it fit for family use; as notwithstanding the utmost attention in grinding, and the greatest exertion of the prefs, some portions of the fruit remain unbruised, which contain juice in an unexpressed state. It is found that the residue of a quantity of fruit, sufficient for making three hogsheds of cyder, is capable of yielding about one hogshed of washings.

Fermenting, racking, and casking the liquor.—These are the next operations to be regarded in the manufacture of this liquor. It is suggested by Mr. Crocker, that cyder making is thus far a mere manual operation, performed with very little skill in the operator; but that now it is that the great art of making good cyder commences: nature soon begins to work a wonderful change in this foul-looking, turbid, fullsome, and unwholesome fluid; and, by the process of fermentation alone, converts it into a wholesome, vinous, salubrious, heart-cheering beverage. He thinks

that philosophy has shown, and that experience justifies the position, that the juices of all vegetables, when exposed to certain degrees of heat and atmospheric influence, are disposed by nature to spontaneous intestine motions of their constituent parts: this is called fermentation.

And it is observed by Mr. Knight, that the juice of the apple in its unfermented state consists of sugar, vegetable mucilage, acid, water, its tinging matter, the principle of smell, and, he believes, of astringency. Of these component parts, the first only is known to be capable of producing ardent spirit, and it might thence be inferred that the strongest cyders would be afforded by the sweetest fruits: but the juice of these generally remains defective in what is termed "body" in liquors, and it is extremely apt to pass from the saccharine to the acetous state. Much of the strength of cyder is supposed by the Herefordshire farmers to be derived from the rind and kernels of the fruit, and hence arises their great attention to grind it thoroughly; the stalks also are necessarily reduced, when the apples are thoroughly ground, and he suspects that the body of the liquor is strengthened, and its flavour improved by the astringent juice of these: yet it does not appear probable, he says, that either of them contains any saccharine matter.

It is further stated as well-known that there are various stages of fermentation in the juices of all vegetables, each of which changes the very nature and quality of the fluid; but the principal ones which are to be particularly attended to, in the instance now under consideration, (the must or juice of apples,) are these; namely, the vinous, the acetous, and the putrefactive. The first converts the must from its turbid, fullsome state, to a transparent spirituous liquor, lightly piquant on the palate, resembling wine both in its flavour and effects.

The above writer states in addition, that it has been observed to take place in such bodies only as contain a considerable portion of sugar, and that it is always attended with the decomposition of that substance. The liquor gradually loses its sweetness, acquiring an intoxicating quality, and by distillation affords a greater or less quantity of ardent spirit, according to the quantity of sugar it originally contained, and the skill with which the process has been conducted. When this fermentation proceeds with too much rapidity, it is often confounded with the acetous, but the products of that are totally different. A violent degree of fermentation however, though purely vinous, is extremely injurious to the strength and permanence of cyder, probably owing to a part of the ardent spirit being discharged along with the disengaged air or gas.

"If," says the author of the *Treatise on Cyder-making*, "the juice has been expressed from four apples, this fermentation is perfected in two or three days; but if from sweet apples, not under a week or ten days, and sometimes longer."

The next succeeding stage of fermentation gives an acidity to the vinous liquor before spoken of, converting it to a sort of vinegar. This fermentation begins soon (frequently in a few hours) after the vinous is ended, and if the fermentation be improperly hastened by heat, before the vinous can be perfected. And Mr. Knight has remarked that it usually succeeds the vinous; but that it will sometimes precede it, when the liquor is in small quantity and exposes a large surface to the air. In this process, vital air is absorbed from the atmosphere, and the ardent spirits, vegetable acid, and sugar, if any remain, are alike converted into vinegar.

It is also further remarked that in the putrefactive process which follows the acetous, the vinegar loses its acidity,

becomes foul and viscid, and emits air of an offensive smell : an earthy sediment subsides, and the remaining liquid is little but water. But although we cannot, Mr. Crocker thinks, form any clear and distinct knowledge of the precise manner in which nature performs these changes in fermenting liquors, yet the effects are evident ; and from a consideration of the different natures and results of the various fermentations, it may be perceived, that the first is the only one useful in making good cyder, and that the others tend to vitiate, and render unwholesome a liquor that would otherwise be highly pleasant, and truly salutary. To regulate the first and to check the others, is then, says he, the greatest business of that cyder-maker, who would attach to himself the satisfaction and fame which every one is envious of acquiring and deservng.

In the view of attaining these ends, fermentations should not, he thinks, by too much heat, be carried on rapidly, nor by extreme cold, too slowly ; as, in each case, the fermenting body must be injured. Hence (he says) it appears, that a certain degree of warmth, or rather imperceptible heat, conduces best to regulate this operation. This degree of warmth may be understood to rest between forty and fifty degrees of Fahrenheit's thermometer. If then the warmth of the cellar, in which new-made cyder is placed, be between these points (no adventitious cause intervening), we may expect that the vinous fermentation will commence and go on with due regularity, and in a proper manner.

It has been observed above, that fermentation is an intestine motion of the parts of a fermentable body. This motion, in the present case, is always accompanied with an evident ebullition ; the bubbles rising to the surface, and there forming a scum, or soft and spongy crust, over the whole liquor. This crust is frequently raised and broken by the air as it disengages itself from the liquor, and forces its way through it. This effect continues whilst the fermentation is brisk, but at last gradually ceases. The liquor now appears tolerably clear to the eye, and has a piquant, vinous sharpness upon the tongue. If in this state the least hissing noise be heard in the fermenting liquor, the room is too warm ; and atmospheric air must be let in at the doors and at the windows.

" This (continues he) is the critical moment, which the cyderist must not lose sight of ; for, if he would have a strong, generous, and pleasant liquor, all further sensible fermentation must be stopped. This is best done by racking off the pure part into open vessels, which must be placed in a more cool situation for a day two, after which it may again be barrelled, and placed in some moderately cool situation for the winter. The Herefordshire cyder-farmers, after the cyder has perfected its vinous fermentation, place their casks of cyder in open sheds throughout the winter : and, when the spring advances, give the last racking, and then cellar it. In racking, it is advisable that the stream from the racking-cock be small, and that the receiving-tub be but a small depth below the cock : lest, by exciting a violent motion of the parts of the liquor, another fermentation be brought up.

Though in common practice the racking of the liquor is rarely much attended to, especially for some months after casking, this being the old method ; there cannot, however, be much doubt but that it should be accomplished at the proper moment as shown above : in proof of which it is found that in the management of the finer liquors, in some districts, in which the fermentation is rapid, some have servants in constant attendance to watch its progress, racking it when necessary, even in the night, as such saccharine li-

quors require timely checking to prevent their taking on the acetous state.

But though frequent rackings have, without doubt, a tendency to reduce the liquor to a quiet state, the strength is supposed to be considerably lowered by it, in consequence of the continual escape of the spirit by exposure to the atmosphere. Brandy, or any other clean spirit may likewise be employed for the same purpose as racking, if not found too dear. The same object may also be obtained in some measure by leaving the cask unfilled, with an ullage. Where the tendency to fermentation is great, the casks should not be too much filled to the bung-hole, the action of the air on the surface of the liquor being favourable to the checking of that process.

The grounds, lees, or feculence of the cyder, after racking, may be strained through filtering bags, made for the purpose, of coarse linen or hempen cloth, and the running placed among the second-rate cyders ; but by no means should it, in Mr. Crocker's opinion, be returned to the prime cyder. Some find it useful in checking any farther irregular fermentation in the casks. In this situation the cyder will, in course of time, by a sort of insensible fermentation, (the same writer says) not only drop the remainder of its gross lees, but will become transparent, highly vinous and fragrant.

" But, (it is observed by Mr. Knight,) that after the fermentation has ceased, and the liquor is become clear and bright, it should instantly be drawn off, and not suffered on any account again to mingle with its lees ; for these possess much the same properties as yeast, and would inevitably bring on a second fermentation. The best criterion to judge of the proper moment to rack off will be (he says) the brightness of the liquor ; and this is always attended with external marks, which serve as guides to the cyder-maker. The discharge of fixed air, which always attends the progress of fermentation, has entirely ceased ; and a thick crust, formed of fragments of the reduced pulp, raised by the buoyant air it contains, is collected on the surface. The clear liquor being drawn off into another cask, the lees are put, he says, into small bags, similar to those used for jellies, being made, as noticed above : through these, whatever liquor the lees contain gradually filtrates, becoming perfectly bright, and it is then returned to that in the cask, in which it has the effect, in some measure, of preventing a second fermentation, as already hinted. It appears, he says, to have undergone a considerable change in the process of filtration. The colour is remarkably deep, its taste harsh and flat, and it has a strong tendency to become acetous ; probably by having given out fixed, and absorbed vital air. Should it become acetous, which it will frequently do in forty-eight hours, it must not, on any account, he says, be put into the cask. If, however, the cyder, after being racked off, remains bright and quiet, nothing more is to be done to it till the succeeding spring ; but if a scum collects on the surface, it must immediately be racked off into another cask ; as this would produce bad effects, if suffered to sink. If a disposition to ferment with violence again appears, it will be necessary, he thinks, to rack off from one cask to another, as often as a hissing noise is heard. The strength of cyder is much reduced, he says, as noticed above, by being frequently racked off ; but this, he supposes, arises only from a large portion of sugar remaining unchanged, which adds to the sweetness, at the expence of the other quality. The juice of the fruits which produce very strong cyders, often remains muddy during the whole winter, and much attention must frequently be paid, to prevent an excess of fermentation.

The casks into which the liquor is put, whenever racked off, should always have been thoroughly scalded, and dried again; and each should want several gallons of being full, to expose a larger surface to the air of the atmosphere.

But, says he, should the cyder-maker neglect the above precautions, the inevitable consequence will be this: another fermentation will quickly succeed, and convert the fine vinous liquor he was possessed of into a sort of vinegar; and all the art he is master of will never restore it to its former richness and purity.

When, however, the acetous fermentation has been suffered to come on, the following attempts may, he says, be made to prevent the ill effects of it from running to their full extent. For this purpose several means have been tried, sometimes with a degree of success, at other times wholly unavailable; the most popular ones would, however, seem to be these: as already noticed, a bottle of French brandy, half a gallon of spirit extracted from the lees of cyder, or a pailfull of old cyder, poured into the hoghead soon after the acetous fermentation is begun: but no wonder, continues he, if all these should fail, if the cyder be still continued in a close warm cellar. To give effect to either, it is necessary that the liquor be as much exposed to a cooler air as conveniently may be, and that for a considerable length of time. By such means it is possible fermentation may, in a great measure, be repressed; and if a cask of prime cyder cannot from thence be obtained, a cask of tolerable second-rate kind may. These remedies are innocent; but if the farmer or cyder-merchant attempt to cover the accident, occasioned by negligence or inattention, by applying any preparation of lead, let him reflect that he is about to commit an absolute and unqualified murder on those whose lot it may be to drink his poisonous draught. Such means should, therefore, on no account be ever had recourse to.

The practice which is provincially termed *flumming*, and which signifies the fuming a cask with burning sulphur, may sometimes be advantageous. It is thus performed: take a stripe of canvas cloth, about twelve inches long and two broad; let it be dipped into melted brimstone: when this match is dry, let it be lighted, and suspended from the bung of a cask (in which there are a few gallons of cyder) until it be burnt out. The cask must remain stopped for an hour or more, and then rolled to and fro, to incorporate the fumes of the match with the cyder; after which it may be filled. If the *flumming* be designed only to suppress some slight improper fermentation, the brimstone match is sufficient; but if it be required to give any additional flavour to the cyder, some powdered ginger, cloves, or cinnamon, &c. may be strewed on the match when it is made. The burning of these ingredients with the sulphur will convey somewhat of their fragrance to the whole cask of cyder; but to do it to the best advantage, it must be performed as soon as the vinous fermentation is fully perfected.

It is stated by Mr. Crocker, that when the cyderist has succeeded in obtaining a favourable vinous fermentation, and by a well-timed racking and attention he has prevented the acetous and other succeeding fermentations from rising, his cyder will require very little further attention, more than filling up the vessels every two or three weeks, to supply the waste by the insensible fermentation, until the beginning of the succeeding March; at which time it may be reasonably expected he will find his cyder bright, pure, and in a fit state for its final racking. This should be done in fair weather; and, if necessary, a commixture should now be made of the high-coloured cyder, made from the Jersey,

or the luscious sweet apples, with that of the pale-coloured cyder from the poorer four apples: by which means a general regular colouring may be obtained with the least trouble, and without expence in any way.

Though it may be expected that the cyderist will now find his liquor to his mind, both in point of brightness and colour, yet should he be disappointed, this is the time for applying some innocent remedy to remove the disorder. He does not recommend to him either of the *forces* commonly used for fining liquors, namely, bullock's blood, isinglass, eggs, &c. as they as frequently spoil a cask of cyder as improve it; but if he put two pounds of lump sugar into a hoghead of cyder, he will receive all the benefit which may be expected from the most nauseous *force* which nastiness can employ. If higher colour in cyder be desired than what his fruit naturally gives under the foregoing management, the cyderist will do well, he says, to melt a pound of lump-sugar in a stewpan, over a clear fire, stirring it frequently, until it comes to a very dark brown colour; then to take it off the fire, and, as it cools, add some cyder thereto by little and little, and continue stirring it until it becomes a thin uniform fluid. This colouring, in the quantity of about a pint, more or less as occasion may require, to a hoghead, is very cheap and wholesome, tinges to perfection, gives no luscious sweetness, but rather an agreeable bitterness, and thus recommends itself to the nicer palates. Soon after this spring racking, but not till then, the casks may be gradually stopped, by first laying the cork on the bung-hole, and in a few days forcing it very tightly into it, covering it over with a layer of melted rosin, or other similar substance.

Bottling the Liquor.—This is the next business to be attended to in the management of cyder; and it is stated by the writer just mentioned, that in the month following, that which is named above, the cyder, in general, will be in a fit state for this operation; but that the critical time for this process is when the liquor has acquired in the cask its highest degree of perfection: then, when the weather is fair, the barometer high, and the wind in some northerly point, let the bottles be filled, setting them by uncorked until the morning; then let the corks be driven very tightly into the necks of the bottles, tied down with small strong twine or wire, and well secured with melted rosin, or other material of the same nature.

It is stated by Mr. Knight, that cyders which have been made from good fruits, and have been properly manufactured, will retain a considerable portion of sweetness, in the cask, to the end of three or four years; but that the saccharine part, on which alone their sweetness depends, gradually disappears, probably by a decomposition and discharge of fixed air, similar to that which takes place in the earlier stages of their fermentation. Cyder is generally in the best state to be put into the bottle at two years old, where it will soon become brisk and sparkling; and if it possesses much richness, it will remain with scarcely any sensible change during twenty or thirty years, or as long as the cork duly performs its office, or resists decay.

But in making cyder for the common use of the farmhouse, the same writer says, few of the foregoing rules are or ought to be attended to. The flavour of the liquor is here a secondary consideration with the farmer, whose first object must be to obtain a large quantity at a small expence. The common practice of the country is sufficiently well calculated to answer this purpose; the apples are usually gathered and ground as soon as they become moderately ripe; and the juice is either racked off at once, as soon as it becomes bright, or more frequently conveyed

from the prefs immediately to the cellar. A violent fermentation soon commences, and continues until nearly the whole of the saccharine part is decomposed. The casks are filled up and stopp'd early in the succeeding spring, and no further attention is either paid or required. The liquor thus prepared may be kept from two to five or six years in the cask, according to its strength. It is generally harsh and rough, but rarely acetous; and in this state, the writer believes, it is usually supposed to be preferred by the farmers and peasantry. When it has become extremely thin and harsh by excess of fermentation, the addition of a small quantity of bruised wheat, or slices of toasted bread, or any other farinaceous substance, will, he says, much diminish its disposition to become sour. But the above opinion is not, he thinks, well founded; they like it best when it possesses much strength with moderate richness, and when it is without any thing harsh or sour in its flavour; but they will drink it, and to a most extraordinary excess, even when it is really in the acetous state.

And, as has been seen above, an inferior kind of liquor is made, the writer says, by macerating the reduced pulp, from which the cyder has been pressed, in a small quantity of water, and regrinding it. This may be kept till the next autumn, and usually supplies the place of cyder in the farm-house for all purposes, except for the labourers in the harvest. It is generally fit to drink very soon after it is made; and though no attention is ever paid to it during its fermentation, it often remains, till near the end of the succeeding summer, more palatable than the cyder pressed from the same fruit, which is a fortunate circumstance for the farmer.

In the business of making perry, which is a liquor of a somewhat similar nature, there is but little which is materially different in the process. See PERRY.

Produce and application of Cyder.—The produce of this liquor is a matter which is extremely difficult to ascertain, whether the quantity be taken by the acre, or in any other way. It has been stated by the author of the "Present State of Husbandry," in this country, that the quantity of cyder and perry made for sale in the fruit districts is very great; but that, that used by the inhabitants is by various accounts much more considerable. These liquors are, he says, sold by the farmers in different states of preparation for market. Sometimes they are sold immediately from the prefs, sometimes after the first racking, and frequently, not until ready for use. The price of cyder and perry always advances according as these liquors are in a prepared state for the consumer's use, as well as according to the quantity on hand, and the quality of the fruit whence it was made. Stire cyder and squash-pear perry, for instance, says he, always give much higher prices than what is made from any other sorts of fruit. The price of common cyder liquor from the prefs, for a course of seven years, may, he thinks, be rated at from 15s. to 30s. the hoghead of 110 gallons; and common perry from 12s. to 15s. Stire-cyder, in the same state, sells for 5l., 10l., and sometimes 15l. the hoghead; and squash perry, in ordinary seasons, from 4l. to 8l. the hoghead.

But the produce of cyder or perry by the acre can only, he says, be guessed at by first ascertaining the number of trees. From an orchard of trees, in full bearing, half a hoghead of cyder may, in seasons ordinarily favourable, he thinks, be expected from the fruit of each tree. As the number of trees on the acre varies from ten to forty, the quantity of cyder must vary in the same proportion; that is, from five to twenty hogheads. Pear trees, in equally good bearing, yield fully one-third more liquor; therefore, although the liquor extracted from pears sells at a lower price

than that produced from apples, yet the value by the acre, when the number of trees is the same, is nearly on a par.

Mr. Vancouver, in his Survey of the County of Devonshire, has remarked, that the great uncertainty of this sort of crops renders it a matter of great difficulty, to state any thing like an average produce of that district. He has found, however, that the mean, of several statements taken upon a period of seven years, which varied from two and a half to five hogheads per acre, will be found to equal that of three hogheads and two-fifths for the acre. And that the average price of the liquor at the *pound's* mouth, or prefs, was, in 1807, fifty shillings the hoghead.

And the intelligent writer of the Report of the County of Gloucester, has offered a statement of the expence, produce, and profit of this kind of crop, in a different way on the extent of twenty acres.

Supposing the distance of planting the trees to be sixteen yards, the acre will admit sixteen stocks, which, with the original cost, planting, and fencing, may be estimated at 5s. each, or in the whole 4l.

Grafting, protecting, and keeping up fences till the trees are out of danger, may be stated at 2s. 6d. each.

It is suggested, that the return to the landlord will be very small for the first twenty years; and that he will not be able to put an additional rent on his lands, in less than thirty years, for the plantation.

The cost of erecting a cyder-house and mill stated at eighty pounds.

General Estimate.		£.	s.	d.
Planting 20 acres	-	8	0	0
Grafting, protecting, repairing, &c.	-	40	0	0
Interest for 30 years on 80l.	-	120		
Building cyder-house, &c.	-	80		
Total expence		320	0	0

	£.	s.	d.
Interest of 320l.	16	0	
Profit	14	0	
		30	0
Advance of rent on 20 acres		30	0

Consequently the landholder has the distant prospect, he says, of increasing his income 14l. per annum, or of receiving nearly 10 per cent. for money laid out, but subject to the deductions of repairs, &c.

But that, with the tenant the advantages are still less certain. Suppose the ground to be so well planted and grown as to contain sixteen trees capable of affording in a good season sixteen barrels, or 800 gallons of cyder, which is a large average allowance; and suppose the liquor to be sold from the mill at 4d. the gallon, the produce will be 13l. 6s. 8d. per acre, subject to the deductions of 20s. for tythes, 2l. for making, 10s. for gathering; in the whole 3l. 10s.: the remainder, 9l. 16s. 8d. will be clear profit; which, if it occurred every year, it would be considered highly beneficial; but a good crop rarely happens oftener than once in four years, while the damage done to the grass under the trees is continued, as well as the increased parochial rates from the increased rent; it does not seem, therefore, the writer says, that the additional rent on account of the trees, is returned with much interest.

Though there are many individuals in the cyder districts who evince much care and attention in the management of

their orchard-grounds, trees, fruit, liquor, &c.: Yet this is by no means, he says, the common case; on the contrary, such general negligence prevails, and so imperfect are the modes in which this branch of husbandry is for the most part conducted, that many are of opinion, so much valuable land being occupied as orchards, is, in a national view, extremely unprofitable; and that owing to the same causes, want of attention, and adopting improper modes of management, the farmers at large are also injured, rather than benefited. While, says he, orchards continue to be considered as secondary objects only of the farmer's attention, as is the case at present, it can hardly be expected that the produce will be abundant, or the quality such as to recommend it to more general notice. In place, however, of condemning orchard husbandry at large, it appears much more correct, he thinks, to recommend a general reform in the management; whereby liquors, that are both wholesome and agreeable, when well made, may be introduced into more general use, and so large an importation of foreign vinous liquors be rendered unnecessary. In place of planting only ten or a dozen of trees on the acre over an extensive tract of land, it would, he supposes, be more for the interest, and certainly much more convenient for the cydermen, were they to allot a few acres adjoining to their places of residence, for the sole purpose of growing fruit-trees. The loss and inconvenience of having fruit trees scattered over an arable field, are considerable. When the trees are full grown, they overshadow, and consequently greatly injure the crop below; the roots also spread to a great distance, and besides impeding the ploughing of the ground, extract a great share of the nourishment that would otherwise go to support the crop of corn. The additional expence in gathering and carrying home a crop of fruit from an extensive fruit-ground, beyond what is incurred when four trees stand on the same space of ground which in the other case is occupied by one, also merits attention. Inconveniences as great and numerous result from having fruit-trees thinly scattered over a pasture field. The grass under the shadow of the trees is very inferior to that in the open part of the field. The cattle must, says he, be excluded when the fruit-trees begin to ripen, especially during and immediately after high winds, otherwise they would eat the fruit. The falling of leaves in autumn is very destructive to pastures of all descriptions; and the same additional expence and trouble of gathering and carrying home the crop are also incurred. For these reasons, a close planted cyder-orchard must, he thinks, be preferable to fields; and where the soil and situation are proper, the grounds stocked with full-bearing trees of the best sorts; and when the trees, the fruit, and the liquor, are judiciously managed, it is impossible but, according to the produce and prices above-stated, such grounds must turn out profitable, even supposing they produce but one crop equal to that above-mentioned, every third year. On the other hand, if the slovenly manner of conducting the various operations of cyder-making be persisted in, it would be in favour of the nation, and of the individuals concerned in that branch of husbandry, he supposes, that there were not a cyder-orchard in the island. Perhaps, on another account also, it might be for the interest of the farmers in the fruit districts that orchards were abolished: the quantity of cyder annually used by the servants and labourers is so immense, that considering the injury which the crops of grain and grass sustain from the land's being incumbered with trees, the labour of collecting and carting home the fruit, and the trouble attending the

manufacturing it into liquors, this beverage must be a more serious article of expence than the generality of cyder farmers are disposed to allow.

It is, however, stated by Mr. Rudge, that where the management of these sorts of liquors is perfectly known and attended to, and there is a capital sufficient to prevent the necessity of immediate sale, as well as plenty of casks in the farmer's own cellar, he may be enabled to take the advantage of the most favourable circumstances of bringing it to the market, as when there is a scarcity from early sales, and no supplies expected from crops of succeeding years; when the price is frequently increased to 8*d.* or 1*s.* the gallon.

It is added, that old cyder is always valuable, and pays for keeping; which is suggested as the best means of countervailing the uncertainty of crops, though it oftener benefits the dealer than the grower of the fruit.

The same able writer also states, that farmers who live contiguous to canals or navigable rivers, have peculiar advantages from their situations, often turning long keeping fruits to a better account than grinding them for cyder, by sending them into the interior districts of the kingdom for the purpose of the table, at the price of 16*s.* per team: "for," says he, "supposing that eleven teams of nine pecks each, are required for 100 gallons, the cyder should be sold at 8*s.* 16*s.* to equalize the profit of their sale unground; but cyder, in its early state, seldom averages more than 9*s.* per gallon, which would be only 3*s.* 15*s.*; so that even supposing all the cyder to turn out well, the former method is far the more advantageous. It is therefore conceived, that in this way alone, the profits of a fruit estate can be satisfactorily made out in favour of the tenant of it. See ORCHARD, and APPLE-tree.

CYDER-Cask, in *Rural Economy*, a vessel of the barrel kind, made use of for the purpose of keeping the liquor. They are of various sizes or dimensions, according to the extent of the fruit grounds, and the fancy and circumstances of the farmer, in so far as capital is concerned. It is, however, commonly supposed that the strength of the liquor is better preserved, if not increased, by a large quantity or body of it being kept together. Though casks of this sort are made to hold from 400 to 500 gallons, the most general size is 110 gallons, which is alone employed in sending out the cyder for sale. The usual price of this kind of casks is about five-pence the gallon.

It is observed that the choice of proper vessels for keeping the liquor in after it has been fermented, is a very material point to be regarded, as none is so liable as this to take the taste or twang of the cask: new vessels, though the wood be ever so well seasoned, are apt to give a disagreeable relish to all liquors, and remarkably so to cyder, unless due caution be used beforehand. Frequent scalding with hot water, into which some handfuls of salt have been first thrown, or with water in which some of the pommage has been boiled, and washing afterwards with cyder, are the usual remedies against this evil, and seldom fail of removing it effectually. Of all sorts of old casks, beer vessels are the worst, as they always spoil cyder; and in return cyder casks infallibly spoil beer. Wine and brandy casks do very well, provided the tartar adhering to their sides be carefully scraped off, and they are well scalded. These different circumstances should always be carefully attended to, in cleaning and preparing casks of this kind for the reception of the liquor.

CYDER-Cloths, are such cloths as are manufactured for the purpose of the cyder-maker, being made use of for

containing the pommage, in order to its undergoing the operation of the prefs. They are usually formed of common hair-cloth, but which is of the more close and compact nature or texture.

The size is generally about four feet square; and they hold about two or three bushels, or as much as the mill can grind at once; and these are, as has been seen, heaped over each other until the prefs is full, being kept to an uniform size by a wooden frame or gauge. The larger presses are capable of holding from eight to fifteen bags or cloths, which yield from one to two hundred gallons of liquor, according to the largeness of what is termed the *cheefe*. To perform the work neatly, it is necessary to have two sets of these cloths or bags, as they are apt to clog and fur in pressing, and consequently become unfit for use again till they have been washed and dried; so that while this is doing, either the prefs must stand still, or another set be ready to employ it. But some, instead of cloths or hair-bags, lay dry straw under the pommage, the ends of which they turn up over it; then cover the pommage entirely with fresh clean sweet-smelling straw, upon which they spread another layer of pommage; and so on alternately, until the prefs is full. Either of the methods will answer the purpose: but those who are desirous of doing the work in the neatest and best manner, generally use hair bags or cloths in performing the business. See CYDER.

CYDER-Kin, an inferior sort of fruit liquor, which is made after the better kind has been prepared, in the manner which has been noticed in speaking of cyder. (See CYDER.) It is mostly used for domestic purposes.

CYDER-Mill is that sort of machine or contrivance, which is constructed for the purpose of crushing, grinding, and reducing apples, or other similar fruits, into the state of a fine pulp or pommage, in order that the juice or liquor may be drawn from it, by means of pressure. In different districts there are variations in the manner of constructing these mills; but they chiefly consist of two kinds, the horse and the hand mills; the former being principally in use where the extent of fruit ground is considerable, but the latter mostly where the farms of this kind are small, and insufficient to repay the expence of such large machinery.

The first sort, or *horse-mill*, which is that by much the most generally met with, is commonly constructed somewhat on the same principles as those in use for the purpose of grinding bark for the tanners; and consists of the following distinct parts, namely, the cistern-chase, or trough, the runner or bruising-stone, and the cog-wheel and upright axle-tree, with the stirrer, the reever, and the shovel employed in the process.

It is stated by Mr. Rudge, in his "Agricultural Survey of Gloucestershire," that the cistern is circular, and formed of stone, being hollowed out in such a manner as to fit and receive the runner, commonly to the depth of about nine inches. On the inner side, or that which is next, what is usually termed the "nut" or central space, it is cut out in a perpendicular form, but on the exterior or outside somewhat in a sloping direction, being left wider across at the top than at the bottom; and the outside upper edge is left two or three inches in width, in order to receive what is denominated a "curbing," which is made of wood, and raises it four inches higher, being finished with nearly a sharp edge. The design of this wood-work is not merely to prevent the pulp or pommage from being carried over, as the stone rolls or turns round, but likewise to correspond with a four-inch plank or planks, which cover the nut, or

circular vacant space in the centre. It is usual for the cisterns to be delivered from the quarries in three or four separate parts, which are afterwards fitted and cramped together by the mill-wright. A cistern of thirty feet in circumference will be requisite for a mill of the ordinary size; and the price is regulated by the number of gallons which it is capable of containing, or at the rate of one guinea the foot in diameter.

In regard to the runner or bruising stone, it is seldom less than three feet and a half, or more than four feet in diameter, being made perfectly flat on the side next the nut, but a little convex on the other, nearly fitting the bottom of the cistern. In the middle, a strong axle of wood is fastened through it, which is connected with an upright or standard axle-tree in the centre, which extends sufficiently far from the exterior side of the runner to connect by means of an iron rod with a wooden bar, which is also linked to the upright axle, and to which the horse is fastened. This wooden bar or pole is so fixed as to be before the runner, and keep the horse clear of it. The height is regulated by a substructure of stone work under the cistern or chase.

To the horizontal axle is fitted a cog-wheel of from eighteen inches to two feet in diameter, which runs on the wood-work that covers the whole space; from the interior edge of the cistern to the perpendicular axle, and which is denominated the nut. The exact height of this wheel must consequently be determined by that of the centre of the runner above the nut. The cogs of this wheel catch upon upright teeth, fixed in the nut, as it rolls upon the surface, and by this means force the stone into a rotatory motion, which under other circumstances it would not always keep; as when the apples are first introduced, or when the bottom of the cistern has become smooth from the pulp, it might slide along rather than roll, was it not for some machinery of this nature; though some mills are without it notwithstanding.

The perpendicular axle-tree has an iron pin at each end as pivots, which runs in a sunk iron centre; the wood of the axle, which is bound with an iron ring or hoop, forming the shoulder of it.

The runner, or stone for grinding, is commonly sold at the quarry at the rate of one guinea the foot, or as many guineas as the stone measures feet in diameter; being, in the district mentioned above, procured from the forest of Dean. They are a sort of dark reddish kind of grit stone, not calcareous, but of sufficient hardness.

It is suggested by Mr. Marshall that much depends upon the quality of the stone. It should not be calcareous, either in the whole or any part, as the acid of the liquor would, in that case, corrode and decompose it. Some of the stones in Herefordshire have, he says, calcareous pebbles in them, which being dissolved as above, of course leave holes in them. Nor should the stone be of such a kind as to communicate a disagreeable tinge to the liquor.

The same writer remarks likewise that there are some mills of this kind which have two runners, one opposite the other. And he thinks that the situation of these mills should be such as to have a horse-path, of about three feet in width, between the bed and the walls; consequently, a moderate sized mill, with its horse-path, takes up a space of fourteen or fifteen feet in every direction.

At Fig. 1. in Plate XI. on *Agriculture*, an improved mill of this sort is represented, in which A is the runner or stone, B C D the cistern-chase or trough, in which the

stone moves and reduces the apples; *EFG* the horse-path; and *HI* the manner in which the moving power is attached.

The other appendages of the cyder-mill noticed above may be thus described:

The *stirrer* consists of a strong round stick, with which the fruit is constantly kept to the stone, and removed from the sides to the bottom, during the process of grinding; for which purpose, a woman or boy usually walks either before or behind the horse. Some horse-mills have two stirrers, so attached to the axle-tree of the runner as to execute the work effectually without manual assistance.

The *receiver* is a small piece of board securely fastened to a wooden handle, and so formed as to fit the shape of the cistern; by means of which, when the pommage or pulp is sufficiently ground, it is drawn together in order to be conveyed to the press by the shovel.

The *shovel* is a tool somewhat of the spade kind, mostly made of wood, being a sort of scoop, by which the above operation is readily performed. Iron shovels are, however, sometimes made use of; but a portion of the iron is supposed to be dissolved by the acid of the liquor, which may possibly contribute to the black tinge frequently noticed in cyder, after exposure to the air. Wooden implements should therefore, of course, be preferred, as being more cleanly, and, at the same time, free from this sort of danger.

The second sort, or *hand cyder-mill*, is constituted of two toothed or indented wooden cylinders of about nine inches in diameter, each being inclosed in the manner of other mills, having a feeder at the top, and being made so as to be turned by the hand. By this sort of mill, the work of bruising the rind, kernel, and stalk, as well as that of reducing the fleshy parts to a perfect pulp, is well performed. From the circumstance of the cylinders being so arranged as to be capable of being removed to a greater or less distance from each other, the business advances in a regular progressive manner, from the first cutting of the fruit until the cylinders are brought so close together that a kernel cannot pass without being bruised; and where another pair of finer toothed cylinders are had recourse to, to work under these, so as to bring the pulp into a perfect state of fineness, the business is still more effectually executed. But though by this means much time is saved, more strength is required in the operation. It is with difficulty that the same degree of fineness can be effected by the horse-mill, as in spite of the incessant attention of the labourer who has the care of stirring the fruit while under the operation of grinding, and of keeping it to the runner, a large portion is conveyed to the press without having been fully reduced. A mill of this description is shewn at *fig. 2.* in the same plate.

It is observed by the intelligent author of the Report noticed above, that "two disadvantages attach to the hand-mill in its present state, loss of time and increase of manual labour;" it being "difficult, with the assistance of three men, to grind a hoghead in a day;" while "with a horse-mill, from two to three hogheads may be made by a man and woman, or younger person, and one horse;" consequently, its superiority on a large fruit farm is conceived to be decided. It is, however, added, that the hand-mill is capable of being greatly improved in the point of expedition, by the attachment of a large horizontal wheel and horse, as has been done in some manufactories.

It has been remarked by the author of the Rural Economy of Gloucestershire, that from observing the great simplicity and high degree of perfection with which the sugar

mills grind the canes or rather press out their juice between two plain iron rollers, the imperfections of cyder mills appear more striking. It is however noticed that the sugar cane is a long fibrous body; and readily passes through between the rollers: whereas fruit being globular, and of a cellular substance, is not easily laid hold of, or, if caught, has no lengthened fibres to induce it to pass, like the cane, between plain rollers. It has, however, been found, that between fluted rollers it may be made to pass; and in consequence, these rollers are in use, though not common. They are of cast iron, hollow, about nine inches diameter, with flutes or teeth, about an inch wide, and nearly as much deep. In general they are worked by hand, two men working against each other. Between these the fruit passes twice: the rollers being first set wide, to break it into fragments, and afterwards closer, to reduce the fragments. But even this is not, he says, a perfect engine: in the residuum from the press many kernels are found. Besides, the acid of the fruit is liable to corrode the iron, and this, in return, to tinge the liquor, though neither of these inconveniences is acknowledged. In a country, however, where stone is not easily to be had, this may, perhaps, be found the most eligible cyder-mill. But in this district, where stone is sufficiently plentiful, the stone runner and trough seem to be the most eligible mill at present known: though it appears to him highly probable, that, with attention and perseverance, a more perfect machine might be invented. Be this, says the writer, as it may, the present mill appears to be capable of improvement. It is at present an unfinished machine: he means when it is first turned out of the workman's hands: time and constant wear do that, in part at least, which the workman leaves undone. The acting parts of the machine, those which are to bruise the rind, and crush the kernels, are the face of the roller and the bottom of the trough. But instead of their being adapted to each other, in such a manner as to effect these purposes with a degree of certainty, they are left in such rough unfinished state as in a great measure prevents them, during the first fifty years at least, from performing that which is their principal intention. Instead of being worked over, and fitted nicely to each other, with the square and chisel, they are hewn over with the stone-mason's peck only, leaving holes and protuberances which would save even horse-beans from the pressure, much more the kernels of fruit. A runner which has been worn two and twenty years has often holes left in it which would lodge half a dozen kernels with safety. To account for this absurdity seems, he says, impossible: perhaps the roughness was intended to prevent the runner from sliding; but the use of the cogged wheels has superseded this intention. Perhaps it was left to gather up the fruits with greater effect; but surely, deep chisel marks, left in the form of flutes across the face, would have answered this purpose better, and would perhaps have laid hold of and fixed the kernels, so as to serve their being effectually broken, preferable to any other equally simple expedient. Or, perhaps, the custom was established when the uses of the rind and kernel were not known, and time has not yet corrected the error. He has been told, that the roughness is left to cut the fruit the better on its being first put into the troughs: and that on this ingenious principle, some will pick their runners over as often as they wear smooth. To such cyder-makers, he would recommend the hobnail mill, which would come much cheaper, rid work still faster, and save the expense of pecking. Be the origin of folly what it may, says he, it is painful to observe its effect. In this case, however, the folly, and, of course, its effect may be easily removed. Having made the face of the roller as true as the square

and the chissel can render it, work, says he, the bottom of the trough to it, until not a mustard-seed can escape them. The kernels of fruit are hard, slippery, and singularly difficult to fix, escaping pressure in a peculiar manner; and with singular alertness.

It is remarked in addition, that another improvement of the common cyder-mill appears to be much wanted; namely, a method of preventing the materials in the last stage of grinding from rising before the runner; and further, a more mechanical way of stirring up and adjusting them in the chafe. Until these improvements be made, cyder-mills, says he, must remain, what most of them evidently are at present, imperfect machines.

It has been noticed by the same writer, that a mill-house, on an orchard farm, is as necessary as a barn on those of other kinds. It is in general found to be one end of an out-building, or frequently an open shed, under which straw or small implements are laid up when not in use. The smallest dimensions possible to render it in any degree convenient and useful are, he thinks, twenty-four feet by twenty; having a floor thrown over it at the height of seven feet; and a door in the middle of the front with a window opposite; the mill being fixed up on one side of it, and the prefs on the other; as much room as is possible being left towards the door, in the front part, for the reception of fruit and the different necessary utensils.

Mr. Rudge considers the "arrangement of the buildings for the convenience of making and storing fruit liquors as a matter of great importance," though it seems to have been but little attended to on old farms. The mill and prefs being often found in an insulated building at a distance from the cellars; which occasions the employing of a man and boy, with a horse and dray to convey the liquor to the place where it is to be casked, which is a labour that would be unnecessary were the mill house and cellars attached. In some of the more recent erections of this description, the spout of the vat is so contrived as to discharge the liquor through an opening in the wall, into a receiver in the cellar, from which it is distributed with facility to the different casks which are to be filled.

The rest of the utensils belonging to a mill-house are few: the fruit being simply brought in casks or large baskets, and the liquor carried out in pails, or by means of spouts as noticed above. The hair-cloths, mentioned above, are the principal addition to the mill and prefs. The expence of fitting up a cyder-mill house depends, Mr. Marshall says, on the size and quality of the mill and prefs. One of a moderate size, for a farm, may be furnished completely for from twenty to twenty-five pounds. One on a small scale might be furnished for from ten to fifteen pounds: much depending on the distance of carriage of the stone. This expence is usually borne by the landlord. A mill-house substantially fitted up will last many years. He has observed a mill and prefs which, by the date upon them, have been set up more than twenty years, yet they appeared almost as fresh as new. Many of the old mills and presses, which are seen, may, compared with those, seem to be a century old; or the mills more particularly a greater age, and were probably the original mills of the farms they are upon.

These observations shew that considerable attention should be bestowed by the fruit farmer in fitting up and completing his buildings and machinery for the management of this sort of liquor.

CYDER-Prefs, a machine of the prefs kind, contrived for the purpose of forcing the juice from different sorts of fruits after their substance has been reduced to the state

of pulp by means of grinding. They are mostly constructed on the same principles as those of other kinds which are intended to afford a strong or powerful pressure, as the packing and oil-press.

It is constituted, according to Mr. Rudge, of the following parts, a cistern-still, vat, cheeks, or "sifters," cap and screw, lanthorn, bridge, press-blocks, shooter, lever, windlas, and rope.

The cheeks, or sifters, are two strong upright pieces of oak, which are preserved in their situations, by being let into the ground first, and then by the cistern-still, which is a thick piece of timber, extending from one cheek to the other, near to the ground, being open mortised at each end, resting upon a shoulder, and clipping the upright: through these open mortises, and the upright, a strong iron pin is passed, which prevents the cheeks from spreading or giving way in the operation of pressing. A corresponding piece is fixed near the top, which is mortised and fastened in the same manner to the cheeks, through the centre of which the female screw or nut is made, in that case denominated the cap.

What is termed the vat, is a wide plank, with a groove running round it near the edge, or what is preferable, a raised levelled border coinciding with the edge, about an inch in thickness, to prevent the liquor from running off at the sides, and conduct it to the sluice or spout from which it is discharged into the receiver. This vat is firmly fixed on the cistern-still.

The screw, when made of wood, is mostly nine or ten inches in diameter, and which passing through the cap, rises three or four feet to the lower end, which is square; the bridge is hung, by means of a rounded pin, which is a plank reaching from one cheek to the other, being freely moveable up and down, but kept to a regular situation or position by open mortises. The lower end of the screw is left of a larger diameter, when the lever is intended to work in it, being in this case perforated and hooped with iron, but the lanthorn is more frequently fixed upon it. This is made of two circular pieces of wood, less than two feet in diameter, being kept eight inches apart by ten strong pillars, between which a piece of ash or elm timber is occasionally placed, which is termed the lever. There are two of these belonging to the prefs, being used according to the extent of power required, one being shorter and less strong than the other, being capable of being worked by the strength of one man, during the commencement of the pressing; but as the liquor becomes more expressed and when nearly exhausted, another lever of greater length and strength is applied to the lanthorn, and worked by means of the windlas, which is an upright post, turning with an iron pivot in a socket on the ground, and passing through a beam in a rather free manner at the top, being removeable when not wanted. A rope coiled round this windlas, is hung by a loop to the end of the lever, being there secured from springing off, by a wooden pin. The windlas has likewise at proper heights, from two to four bars of wood passing through for the purpose of handles, to which the strength of four men may be applied with much effect. The press-blocks are pieces of oak, about two feet in length, and six inches square, placed one above the other, crossing in alternate pairs, under the bridge, for the purpose of keeping the lanthorn, lever, and rope above the heads of the workmen at the windlas.

It is suggested that iron screws have of late been coming much into use, being either cast or wrought; the price of the former being about 2*l.* 15*s.*; and of the latter nearly 10*l.* The power is supposed by some to be increased by

the fineness of the threads in the iron screw, while others admit of no other superiority but that of durability.

The price of a good press with wooden screw is usually about ten guineas.

It has been suggested by the author of the Rural Economy of Gloucestershire that the situation of the press should be as near the horse path of the mill as convenience and the nature of the building will permit, in order to the more ready conveyance of the ground pommage or pulp from the mill to it. The size of the cyder-press may be different according to the extent of the apple orchard.

An improved *Large Cyder-press* is shewn at *fig. 3*, in which A A is the base or foundation with its supporting parts: B, B, the cheeks or sisters: D D the cross piece at top, through which the screw passes, and which consequently contains the nut or female screw: E the screw with its appendages: F F the bridge or cross piece which acts on the pommage: G G is the wide plank or vat on which the pulp rests in the hair bags; in which the mode of the liquor's passing off is seen: H H (*fig. 4*.) is the windlass, with its handles, wheel, rope, &c.

At *fig. 5*, is seen a small *Cyder-press* of a different kind, which acts by means of a heavy stone or block of wood made of a conical form, moving round the centre by a lever which is inserted into its base, as shewn at A and B: C is the bed of the press, notched for let-

ting off the liquor into the cask or vessel, D, placed below: E, E, E, E, are the feet or blocks on which the whole rests.

CYDER-spirit, a spirituous liquor drawn from *cyder* by distillation, in the same manner as brandy from wine. The particular flavour of this spirit is not the most agreeable, but it may, with care, be divested wholly of it, and rendered a perfectly pure and insipid spirit, upon rectification. The traders in spirituous liquors are well enough acquainted with the value of such a spirit as this: they can give it the flavours of some other kinds, and sell it under their names, or mix it in large proportion with the foreign brandy, rum, and arack, in the sale, without danger of a discovery of the cheat.

CYDER-Vat, is a term applied to that part of the cyder-press which first receives the liquor as it is forced out from the pulp, and by which it is conveyed into the receiver. See *CYDER-Press*.

It is likewise a name often given to the vessels which receive the cyder before it is racked off into the store casks.

It is remarked in the Survey of the County of Gloucester, that the vat is still, in some cases, covered with lead, although the pernicious effects of its being corroded by the acid of the liquor have been frequently experienced. It should on this account be always made of some sort of hard wood.

Cylinder

CYLINDER, *rolling*, in *Mechanics*, a cylinder which rolls up an inclined plane.

The phenomena of the rolling cylinder may be easily accounted for from what we have observed under centre of gravity.

For let $ABED$ (*Plate XXII. Mechanics, fig. 1.*) represent the section of a cylinder of wood, biased on one side by a cylindrical piece of lead, as B , which will bring the centre of gravity out of the centre of magnitude, C , to some point, G , between C and B . Let FH be an inclined plane, whose base is FL . It is evident the cylinder laid upon the plane will nowhere rest but there, where a perpendicular to the horizon, FL , passes through the centre of gravity G , and that point of the plane E , in which the cylinder touches it; and this, in all angles of inclination of the plane less than that whose sine is equal to CG , the radius being CD , will be in two situations $ABED$, and $abed$: because when the cylinder moves, the centre of gravity describing a circle round the centre of magnitude C , this circle will meet the perpendicular in two points G and g , in each of which the centre of gravity being supposed, the cylinder will rest. Therefore the cylinder moves from E to e by the descent of the centre of gravity from G to g , in the arc of the cycloid Gbg .

If the cylinder $ABED$, *fig. 2.* insliding on the horizontal line EL , in the point E , has the centre of gravity G in the horizontal diameter DB , it will gravitate in the perpendicular Gc : if therefore the plane FH touch the cylinder in the point e , it is evident the cylinder cannot either ascend or descend on such a plane. Because G in any situation between e and H , or e and F , will gravitate to the left or right from the point in which the cylinder touches the plane; and so will in either case bring it back to the point e . And as the angle ECe is equal to HFL , it follows, that a cylinder cannot ascend on a plane whose inclination is greater than that angle.

CYLINDER-Boring, is the method of boring out and smoothing cylinders of brass, iron, or other metals, for pump-barrels, steam-engines, &c. &c.

Plate XXIII. Mechanics, is appropriated to the description of a machine for this purpose, designed by Mr. John Dixon, Maid-lane, Southwark, and erected by him at the Falcon iron-foundery.

Fig. 1. is an elevation of the machine, in the operation of boring a cylinder for a steam-engine. *Fig. 2.* is a plan. *Figs. 3, 4, 5,* parts of the machine. *Fig. 6.* an end elevation. *Fig. 7.* a section.

The machine is turned by a steam-engine, which communicates motion by means of a coupling-box, a , to a long iron shaft AB , turning in brass bearings, supported on iron standards C, D , bolted to the two ground sills E, F ; this shaft (called the boring bar) is perforated from end to end, as is shewn in the section, *fig. 3*, and has also a slit, bb , *fig. 1*, through it nearly its whole length; it is turned in a lathe, and thus made a perfect cylinder. Another short cylinder, DD (in the section, *fig. 3*, and *fig. 5*), slides easily upon the boring bar without shake, and is made to turn round with the bar, by two short iron bars, d, d , which pass through the slit, bb , made in the boring bar, and fit at their ends into two notches made in the ends of the short cylinder DD . E is a long screw going within the boring-bar, and of the same length; the end which enters the boring-bar, and which is not cut into a screw for some length, passes through holes made in the middle of the short bars d, d , and is held in by wedges, as in *fig. 3*.

The knives or cutters, e, e, e, e , *fig. 4*, are fixed by wedges in notches round the circumference of a cast-iron ring, *fig. 4*, called the cutter block; the inner circle, G , of the block, is of the same size as the outside of DD , upon which it is placed, and made to turn round with it, by two small wedges driven into notches f, f , made in the inside of the ring, and entering similar notches in the outside of DD .

The cylinder, *II II*, to be bored, is fixed firmly concentric with the boring-bar upon a frame of cast iron, consisting of several pieces, which are moveable, and can be set to hold a cylinder of any length or diameter. The first are four cast iron bars, *l, l, l, l*, with slits through them nearly their whole length; they are firmly bolted down to the ground fills, and support two cross bars *K, K*, which can be fixed at any place along the bars *l, l, l, l*, by screws passing through the grooves. The cross bars, *K, K*, have grooves through them in the direction of their length, to receive screws which fix upon each bar two uprights, *L, L*, at any place.

By this sliding of the two cross bars *K, K*, the fixtures are adapted to the length of the cylinder, and by moving the uprights *L, L*, nearer to or farther from each other, the cylinder is fitted in its diameter, horizontal; the weight of the cylinder is supported by blocks and wedges driven under it upon the cross bars *K, K*, and it is kept down by two strong wrought iron-bands, *r, r*, put over it, and drawn down by screws on the top of the uprights *L, L*.

A cross beam is fixed upon the end of the ground fills, into which an upright beam, *M*, is mortised, and its upper end is supported by the beams of the ceiling; the upright has a socket fixed to it, in which a nut for the screw *E* turns, in such a manner that it cannot move backwards or forwards, though it is at liberty to turn round freely; an iron cross, *m m*, is fixed on the nut to turn it by. The end of the screw, *E*, is square, and has a short cross bar, *n*, pinned on it, which has wheels at its ends, and runs upon a thick plank, *N*, supported on iron legs, *o, o*; at one edge of the plank, a piece of iron plate, *p*, is screwed and turned over at top, to form a groove in which one of the wheels run; the cross bar and plank prevent the screw from turning while it can be moved endways along the plank.

In the working of the machine, the first thing is to fix the cylinder; for which purpose the plank, *N*, must be removed, the screw, *E*, drawn out of the boring bar, the

upright, *M*, and iron standard, *D*, taken away, the weight of the boring bar being supported by blocks put under the middle of it; the cutter block, and the short cylinder *DD*, *fig. 3*, is now put upon the boring bar, the bars, *d, d*, *fig. 3*, being first put through the slit, *bb*, in *fig. 1*, in the bar at its end towards *D*, where it is enlarged for the purpose; the cutters are fixed in the block by wedges, and adjusted, that they may all be at the same distance from the centre, and that they may bore the cylinder of the proper size. The cylinder is now put over the boring bar, and when the end of the bar comes through the cylinder, the standard, *D*, is replaced; the weight of the bar is now supported, and the blocks in the middle can be taken away, to get the cylinder in its place, and fix it fast, as before described. The screw, *E*, is next introduced into the boring-bar, and pinned into the two cross bars *d, d*, as in *fig. 3*, the upright *M*, is fixed, and the nut of the cross, *m m*, screwed upon the screw *E*; the plank, *N*, is set up, and the whole put in the situation represented in the plate, except that the cutter block is seen on the boring bar towards *A*.

The steam-engine is now set to work, and the boring bar thereby turned; a workman turns the cross, *m m*, and with it the nut of the screw *E*; as the screw is prevented from turning by the cross bar, *n*, on its end, the screw is drawn endways, and consequently the cutter block with it, until it meets the end of the cylinder, when the cutters begin to bore, forming a new smooth cylinder, somewhat larger than the old one left by the casting of the cylinder; as the cutters clear the metal before them, they are drawn further into the cylinder by turning the cross, *m m*, until they come completely through. The operation is now finished, and the cylinder is removed in the same manner as it was put in, the machine being left in pieces ready to put in another cylinder to be bored.

A great number of cutter blocks, *fig. 4*, are cast, of different sizes for various cylinders, and they all fit upon the same sliding cylinder, *DD*, *fig. 3*.

Damp

DAMP, *adjective* (from the Dutch *dampe*), denotes a perceptible degree of moisture in any thing; such as in damp air, damp walls, damp apartments, damp linen, &c. The methods of ascertaining the actual existence or degree of dampness in any thing, an examination of the effects which it is likely to produce, and the various ways of removing it, are the objects of philosophy, of medicine, and of civil economy; but as those objects will be particularly noticed in various other articles of this Cyclopædia, such as *evaporation*, *mists*, *fogs*, *hygrometry*, *dew*, &c.; we shall in this place only give a compendious and superficial idea of the whole. Almost all natural bodies, excepting metallic substances, most hard stones, vitrifications, and a few more, contain at all times a certain quantity of water; yet they are considered as being dry, when that quantity of water is not more than that which the affinity of the particles of the bodies to water can retain. But should that affinity (*viz.* that degree of attraction between the particles of those bodies and water) be diminished by any adequate cause, or should the quantity of water exceed that which the peculiar affinity of each body can retain, then the bodies are said to be damp, and they will appear to be so, either by the mere touch of the human hand, or by the indications of hygrometers, and other instruments. Thus, common atmospherical air always contains a quantity of water which is perfectly dissolved in the air, and is retained by every particle of the latter, in virtue of their mutual attraction of affinity. But that affinity is diminished by cold, and is increased by heat; therefore, if a quantity of air be cooled by any adequate means, its affinity to water will of course be diminished, and part of the water it contained will be separated; forming a vapour which in some measure affects the transparency of the air, and is ready to attach itself to any other body which may be presented to it in a state fit for the absorption of vapour. The air in that state is said to be damp, and an hygrometer placed in it will shew it to be so, by its usual movement towards moisture.

On the other hand, if cold air, which appears to be damp from the indications of hygrometers, or from moistening salts, &c.; be rendered much hotter, its affinity to water will thereby be increased, and the appearances of dampness will vanish.

Besides the above-mentioned affinity, there is another power which enables bodies of every kind to retain water; and this is a sort of superficial adhesion. (See *CAPILLARY Attraction*.) It acts most powerfully when a given quantity of water is exposed to the action of a proportionately great quantity of surface; hence, all porous bodies have the power of retaining water to a certain degree, and under certain cir-

cumstances. Therefore, in a variety of bodies both those powers contribute to retain water at the same time, and such most probably is the case with air itself.

Sometimes bodies contain water proportionate to their degree of affinity, yet other bodies will rob them of a portion of that water; and such is the case with dry fixed alkalies, or fresh quick-lime, which will separate water from air apparently very dry. This, however, only proves that certain bodies have a greater affinity to water than air or certain other bodies have.

In certain circumstances a greater quantity of moisture is crowded upon bodies than they can retain; hence they feel damp. Thus, the air which lies contiguous to water generally contains more moisture than the air which is more remote; but the latter by degrees absorbs the superfluous moisture of the former, and thereby enables it to imbibe more of the vapours which rise from the contiguous water; and thus the process of evaporation goes on. But if the free circulation or communication of the air be interrupted, then the air which is confined over the water will hold a considerable quantity of superfluous moisture, and will thereby become damp. Now such is the case with the air of caves, cellars, holds of ships, &c. when any water is contained in those places. From the above statement it evidently appears that heating and ventilation are the two most powerful means of removing dampness. The action of heat diminishes the attraction of solids to water, and increases the affinity between air and the same fluid. Ventilation, when the air is dryer than other bodies, removes dampness by dissipating the moisture through the atmosphere.

From the result of all the experiments that have hitherto been instituted, it appears, that a cubic foot of air saturated with water, contains two grains of water at the temperature of 32° Fah. (*viz.* at the point of melting ice); it contains four grains at the temperature of 48°, six grains at the temperature of 60°, and eight grains at the temperature of 68°.

A remarkable circumstance attends the mixture of aqueous vapour with air, which is, that air thus saturated with vapour is lighter than an equal bulk of dryer air; and this arises from the density of the vapour thus mixed, which is less than the density of the air, in the proportion of three to four, according to Saussure.

The explanation of several natural phenomena may be easily derived from the above-mentioned facts, attending, however, to other concomitant circumstances. Thus, in a calm day, when the air is serene, a cold wind springs up from the north or from the east, the cold air mixes with the warmer, their capacity for containing water is diminished, a

haziness ensues, and the air becomes damp; yet sometimes the cold air is dryer on account of particular circumstances, and though a haziness may at first appear, a perfect transparency will be restored soon after.

It frequently happens, that the vapour which is separated from the air by the action of cold, remains suspended in the shape of a mist or cloud; yet at other times it descends immediately, and attaches itself to terrestrial bodies in the form of dew. But in these phenomena the action of electricity seems to be in great measure concerned. We shall have occasion to examine the nature of those phenomena more at large in other parts of this work.

The effects of damp air, damp clothing, and damp apartments, are variously modified by the climate, by the temperature, and by the customs of the inhabitants, of every particular country.

DAMP, *noun substantive*, (from the Saxon *damp*, a vapour or exhalation,) means a fog, or moist air, or moisture; but it is principally used in the plural, *damps*, to denote certain noxious vapours or exhalations issuing from the earth.

These exhalations frequently occur in mines, coal-pits, wells, and other such like excavations; but sometimes they are also to be met with near the surface of the earth, especially in the vicinity of volcanoes. The noxious quality of such exhalations, and the numerous fatal effects which they have produced, have obliged mankind to collect the various accounts of the phenomena, to investigate their origin, and to contrive methods of preventing their dire effects. But the accounts have been mostly furnished by miners, whose ignorance, whose fears, and whose sufferings, have generally involved the truth in a considerable proportion of exaggeration; yet, from a careful comparison of those very accounts, from the result of experiments instituted by scientific persons, and from the knowledge of the subject of elastic fluids, which has, of late years, been wonderfully promoted; the nature of those damps is at present pretty well ascertained, and their effects may be sufficiently accounted for; excepting, indeed, two or three strange stories, which are in need either of historical confirmation, or of a much deeper philosophical investigation.

The general effect of the damps is a contamination of the common, or respirable, atmospheric air; by the admixture, not indeed of moisture, as one might be led to understand by the name of damps, but of other elastic fluids, which are absolutely unfit for animal respiration. *Carbonic acid gas*, (formerly called *fixed air*,) *azotic gas* (formerly called *phlogisticated air*,) and *hydrogen gas*, or *inflammable air*, are the three elastic fluids which generally, if not always, produce the damps: we shall, therefore, briefly premise the principal properties of these gases; in order that the nature of the damps may be understood without much circumlocution.

Carbonic acid gas is absolutely unfit for respiration or for combustion; inasmuch, that an animal confined in it, will be deprived of life rather sooner than if he were confined under water. A lighted candle or torch brought within a quantity of this gas, is extinguished as readily as if it were dipped in water. This gas is heavier than common air, in the proportion of three to two; hence, when it issues out of the earth in hollow or sheltered places, it remains for a considerable time in a stratum close to the bottom of the place. Carbonic acid gas consists of 72 parts of oxygen, and 28 parts of charcoal.

Azotic gas is likewise unfit for respiration and for combustion. Its specific gravity is very little below that of common air. It is that gas which forms about three-fourths

of the atmospherical fluid, the other quarter consisting principally of oxygen air. It is produced, or rather left by itself, whenever the oxygen of the atmospherical air is absorbed, as is the case in combustion, respiration, and various other processes.

Hydrogen gas is, by itself, utterly unfit for animal respiration; but when mixed with common air, it may be breathed with impunity. In its purest state, hydrogen gas weighs rather less than the twelfth part of an equal bulk of common air; but as it is capable of holding in solution water, sulphur, phosphorus, carbon, &c. so its specific gravity generally exceeds that which has been just stated; it is always, however, much lighter than common air; hence, when it occurs in mines, it is either actually issuing out of crevices, or it is lodged under the roofs of those excavations. This gas is highly inflammable, so that it may be fired by the flame of a candle, or a very small electric spark, or even by a red-hot iron; but, like other combustibles, it will burn only in contact with common, or oxygen, air; hence, if a lighted candle be presented to a certain quantity of hydrogen gas, this will burn either silently and progressively, or suddenly, and with an explosion, according as the common air is contiguous to one side of it, or is more or less intimately mixed with it. The greatest explosion takes place, when four parts of hydrogen gas are mixed with six of common air; the tint of the flame varies according to the substance dissolved in the gas. This gas is produced principally in the decomposition of water; for water consists of oxygen and hydrogen gas; from which circumstance this gas has obtained its name. After the above compendious statement of the nature and properties of the gases which produce the damps, we may proceed to describe the phenomena.

Two sorts of damps have been principally described: one has been called the *choke-damp*, from its suffocating quality; the other has been called the *fire-damp*, from its disposition to take fire, and to burn either gently, or with an explosion.

The choke-damps generally occur in old mines, called *wagles* by the miners; being such as formerly had been worked, but afterwards remained neglected. These damps are likewise frequently met with in old wells, deep cellars, and other subterranean places wherein the air has long remained undisturbed. They are formed by an accumulation of carbonic acid gas, which issues from the ground, and being much heavier than common air, remains next to the bottom, or ground, in a stratum of various depth, and more or less mixed with common air, or with azotic gas. The effects which have been produced by this sort of damp are more than sufficient to manifest the nature of the gas to which it is owing.

The persons who happen to descend within this damp, instantly lose their respiration, and fall down senseless; nor can their death be prevented, unless they are quickly removed into the open atmospherical air; but even this method frequently proves ineffectual. Several cases are recorded, where one person having been suffocated, a second went down with a view to save him; but he also fell, and sometimes even a third person met with the same fate. Persons that have thus lost their lives, on examination, have been found to exhibit all the marks of animals that have been suffocated in carbonic acid gas. One of the surest methods of ascertaining the presence of this kind of damp in a well, mine, &c. is to send down a lighted candle; for if the candle continues to burn, you may conclude that a human being is perfectly safe in it; but if the candle goes out, then

the presence of the damp may be considered as certain; yet the human being may breathe, though not with perfect freedom, in air so far vitiated as not to be capable of supporting combustion. The miners distinguish this last state of the air from that which is completely noxious, by the appearance of the candle; viz. if the flame and the redness or coaly part of the wick vanish at the same time, they conclude that the air is utterly unfit for respiration; but if the redness of the wick continues sometime longer after the extinction of the flame, then they think it not very dangerous to descend into the place.

On account of the superior gravity of the carbonic acid gas, and of its affinity to water, a greater quantity of vapour frequently remains suspended in the choke-damp, than in common air; hence this damp is sometimes visible like a fog or mist, and this is particularly the case in a cavern near Pyrmont.

It frequently happens that the stratum of carbonic acid gas is not higher than two or three feet; so that a man will be perfectly safe in it as long as he remains in a standing position; but should he attempt to lie down or to sit, he would run the risk of being suffocated.

The sudden issue of this damp out of the earth, especially when any digging has been performed, has sometimes instantly killed the workmen.

In all such cases, ventilation (in whatever manner it may be practised) is the best method of dissipating the damp. But should a man be obliged to go down into a place thus infected, either for the purpose of saving another man, or for some other particular purpose, he would do well to fill a bladder with common air, and by means of a short tube fastened to the neck of the bladder, and held in his mouth, to breathe that air; for a bladder thus filled will last him some minutes, during which time a great deal might be done. He might also take with him two or more bladders filled with common air, and furnished with stop-cocks, or merely with tubes stopped with corks.

Cautious miners ought always to have such bladders, or such like bags, filled with common air, by them; for they cost little or nothing, and will effectually save their lives occasionally.

When digging is to be performed in any place where the least suspicion of a sudden issue of the choke-damp is entertained, it will be proper to keep a candle or lamp burning close to the ground; for if any noxious gas happens to come forth, the going out of the flame will afford sufficient warning to the workmen.

The sudden issue of the choke-damp from the earth frequently occurs in the neighbourhood of volcanoes, upon old lavas, and old accumulation of ashes or other volcanic productions. Numerous cases of this sort take place in the vicinity of mount Vesuvius, in Naples, where the noxious vapours, (called *mofete* by the inhabitants,) suddenly enter houses, cellars, &c. to the great annoyance of the inhabitants, who, as well as other animals, are sometimes killed by them. See sir William Hamilton's various accounts of the mount Vesuvius and its eruptions, in the Philosophical Transactions, for 30 or 40 years past. Some of the scientific persons of the above-mentioned country have occasionally endeavoured to ascertain the nature of the gas which produces those mofete; and from their experiments it appears, that the greatest part of the gas is carbonic acid, but more or less mixed with azotic gas, and frequently accompanied with sulphureous and arsenical vapours. A remarkable instance of a continual stream of carbonic acid gas

issuing from the earth, occurs near the city of Naples. At about five or six miles from that city, near the foot of a hill, there is a famous cave called *grotto del cane* in the Italian language. This grotto is about fourteen feet long, and nearly seven feet high at the entrance. On the bottom of it, which is nearly on the same level with the adjacent external ground, there is at all times a stratum of carbonic acid gas or choke-damp, which is continually coming out of the earth, through the fissures which are pretty apparent on the ground; and where the production of such gas has been remarked from time immemorial. Animals of different species, as well as human beings who sheltered themselves in this grotto, were at times found dead in it, in consequence of which a door was placed to the aperture of it, which is now only opened occasionally. The experiments usually shewn to the curious who visit this grotto, are, that of bringing a lighted torch or lighted piece of paper near the bottom or floor; the flame of which is extinguished as soon as it comes within about 14 inches of the ground; and secondly that of confining a dog with its head close to the ground for about a minute. The respiration of the animal is instantly affected, and its strength fails, so as to remain apparently dead; but on being exposed to the ambient air out of the grotto, if it be not too far gone, the poor animal will gradually recover its respiration and its strength. It is from this usual experiment that this grotto has obtained its name: *cane* being the Italian for a dog.

Joannes Caramucis, in his *Mathesis Nova*, printed in the year 1670, relates some experiments made by himself and others upon the noxious elastic fluid of this grotto, which are very remarkable, considering the time in which they were made. He observes, that the smoke of a candle, extinguished near the bottom of this grotto, is entirely retained within the stratum of gas; and that if part of that smoke happened to be driven out of the grotto, it descended like water falling from the edge of a tub. Had he been acquainted with the nature of carbonic acid gas, he would have easily understood that the smoke was retained on account of the great attraction between that gas and the aqueous particles; and that it descended, when driven out of the grotto, on account of the great specific gravity of the carbonic acid gas with which it was combined. The same ingenious person relates another experiment, which tends to prove the acid quality of the gas concerned, which quality has long after been fully ascertained. He and his companions placed the head of an alembic on the bottom of the grotto; and as this instrument was colder than the air of the grotto, which generally is pretty warm, it collected a few drops of a watery fluid, which, to the taste of his companions, seemed to be acidulous. In the present state of knowledge this experiment is easily explained; it being evident that the head of the alembic condensed the watery particles from the air of the grotto, and these became acidulous in consequence of their becoming impregnated with the carbonic acid gas. The ground in the neighbourhood of grotto del cane shews manifest signs of subterranean fires or fermentation, as it abounds with sulphur, hot springs, emanations of smoke, &c.

Fire damp, though considerably heavier than pure hydrogen gas, is yet much lighter than atmospheric air. Hence where a tolerable ventilation is kept up, it seldom accumulates to a dangerous amount in the shafts, or vertical pits, that are open to the air; but in the horizontal galleries, where it occupies the upper part, forming a stratum, lying immediately in contact with the roof. It generally makes its first appearance in the cracks and crevices of the coal,

particularly where it is moist and abounding in pyrites. While it is thus oozing out, it often burns with a quiet light blue lambent flame, which, on the contact of a candle, explodes with a hissing noise, and, for a time, is extinguished or forced into an adjacent crevice. In proportion as the water is drained off, the production of this gas diminishes, so that the driest mines are the least infested with it. Heat contributes much to its generation; hence it is generally more abundant during the summer than the winter months. If it is not cleared out of the mine, in proportion as it is produced, it soon begins to accumulate in the upper part of the galleries, on which account it is a caution well worth remembering, by those who visit a coal-pit, to hold their candles as low down as possible. The gas thus continues to increase without producing any material inconvenience to the miners, till, at length, it comes in contact with some lighted candle: the flame is immediately increased to five or six times its usual size, and in a second or two afterwards, the whole body of gas takes fire: a volume of flame and black smoke darts from the gallery into the vertical shafts, whence it rises into the air with a loud stunning explosion, throwing up, to a considerable height, men, large beams of timber, and every thing else that happens to be in its way. As soon as the explosion has taken place, the external air rushes violently into the mine to fill up the vacuum, and the residual inflammable gas again takes fire, and burns quietly for a few minutes, till it is extinguished.

When an accident of this kind happens, there are three distinct dangers to which the miners within its influence are exposed. In the first place, those who are in the gallery where the inflammation commences are scorched by the fire, and are also liable to suffer severely from the rushing in of the air to supply the vacuum caused by the explosion. Secondly, those who happen to be in the shaft, or near the mouth of the gallery, are either blown up out of the pit, or are killed by being violently forced against its sides. In the latter of these situations there is no possibility of escape; but those who are not exploded, often save their lives by throwing themselves on their faces on the ground, and covering themselves, as well as they can, with small coal, &c. till the danger is past. No particular odour is perceivable before the inflammation, but afterwards a strong and suffocating smell of burning sulphur becomes very obvious.

We shall now give a summary of the facts that were collected from the miners by Mr. Jessop, as given in the Philosophical Transactions, N^o 119.

1. "Those who are in the place where the vapour is fired, suddenly find themselves surrounded with flames, but hear little or no noise; though those who are in places adjacent, or above ground, hear a very great one.
2. Those who are surrounded by the inflamed vapour feel themselves scorched or burnt, but, are not moved out of their places; though such as unhappily stand in the way of it, are commonly killed by the violence of the shock, and are often thrown with great force out of the mouth of the pit; nor are the heaviest machines found able to resist the impetuosity of the blast.
3. No smell is perceived before the fire, but a very strong one of brimstone is afterwards felt.
4. The vapour lies towards the roof, and is not perceived if the candles are held low; but when these are held higher, the damp descends like a black mist, and catches hold of the flame, lengthening it to two or three hands full; and this appearance ceases when the candles are held nearer the ground.
5. The flame continues in the vault for several minutes after the crack.
6. Its colour is blue, something inclining to green, and very bright.
7. On the ex-

plosion of the vapour, a dark smoke, like that produced from firing gun-powder, is perceived. 8. Damps are generally observed to come about the latter end of May, and to continue during the heat of summer. They return several times during the summer season, but observe no certain rule."

The fire-damps generally occur in coal-mines; and in the Philosophical Transactions, N^o 136, we find several accounts and observations made in digging such mines; and from these we shall compendiously extract the most useful particulars.

"After they had gone, the account says, a considerable way under ground, and were scantied of wind, the fire-damps did begin by little and little to breed, and to appear in crevices and slits of the coal where water had been before the opening of the coal, with a small blueish flame, working and moving continually; but not out of its first seat, unless the workmen held their candles to it; and then being weak, the blaze of the candle would drive it with a sudden siz away to another crevice, where it would soon after appear blazing and moving as formerly.

"This mine was neglected for a certain time; and upon a morning, the first collier that went down with his candle in his hand, the damp presently darted out so violently at his candle, that it struck the man quite down, singed his hair and clothes, and disabled him for a while. After the cessation of work for some days, in going down the first time, the fire-damps have often exploded with terrible effects."

The bad effects of the fire-damps may, in a great measure, if not entirely, be prevented by vigilance, and by a proper conformation of the excavations. In digging a mine, due attention ought to be paid to the roof of it, which ought to be shaped so as in some measure to resemble an inverted funnel, viz. having the highest part of it near to the shaft or shank; for, by this means, the hydrogen gas, or fire-damp, would ascend into the atmosphere as soon as it is generated; nor could it be lodged any where in so great a quantity as to produce any dangerous effects. In mines already formed, and especially when they have not been worked for a certain time, it is always proper to let down two or three lighted candles by means of a rope; and if these produce no inflammation, then a man with a candle ought to be sent down, who, after advancing a few steps into the mine, ought to lay himself down, and ought to lift up a lighted candle on the top of a pole as high as he can; for the inflammable gas which always occupies the upper part of the mine, may, in that case, be exploded with hardly any danger to the man.

When miners are actually working in a mine, the accumulation of the inflammable gas may be easily prevented, viz. by firing it off immediately as it issues out of the various crevices.

Ventilation is the best method of removing damps out of mines, and at the same time of giving wholesome air to the labourers; but this is hardly practicable in such mines as are furnished with one shaft or aperture. It is, therefore, always to be wished that mines of any extent should be furnished with two or more shafts in proportion to their extent. The ventilation then may be promoted by lighting a fire under one of those shafts; for by this means the air of that shaft being rarefied, will be forced to ascend, and of consequence an influx of pure atmospheric air will enter the mine through the other shaft or shafts. Several mechanical methods have also been used for the ventilation of mines. The nature of the gas which produces the fire-damp, as well as that which produces the choke-damp, has been fre-

quently subjected to philosophical experiments, with a view to ascertain both its origin and its qualities. Sir James Lowther collected the gas of the fire-damps in bladders, and thus brought it up to London, where, upon trial, he found, that on being let out of the bladders, it would take fire at the flame of a candle. But some recent experiments of Dr. William Henry, on a similar sort of gas, were performed with greater care; and their results, which we shall subjoin, are much more satisfactory.

"About the close, Dr. Henry says, of 1806, I received from the Rev. W. Turner of Newcastle-on-Tyne, two bladders filled with the fire-damp, which had been procured from a coal-mine in the neighbourhood of that town. It

... compressed bladder on the pipe of the funnel, after the gas had issued from it for some time. My experiments were made on the gas, about seven days after its being first collected. At that time the bladders were perfectly dry, and shewed no signs of putrefaction."

The general results of these experiments, (as stated in a memoir which was read in January 1807, before the Medi-

disagreeable smell. When set on fire, as it issued from the orifice of a small pipe, it burned with a dark blue flame; and a long conical glass vessel, held over the flame, was soon bedewed with moisture. Mixed with common air, it did not detonate on the approach of a lighted taper, at least in any proportion that was tried. The utmost effect was a deep blue flame, which spread quickly through the vessel, but was not accompanied with any noise. With oxygen gas, however, it exploded, and gave a loud report. On agitation with lime water, it lost about $\frac{1}{80}$ th of its bulk. The nicest tests did not discover any admixture of sulphurated hydrogen. One hundred parts by measure appeared, therefore, to consist of

63.34 atmospherical air
1.66 carbonic acid
35.00 inflammable gas

100.00

"The nature of the inflammable gas was next ascertained by detonation with oxygen gas. Reducing the results to a general average, and excluding the common air, the really inflammable part of the gas required for combustion about twice its bulk of oxygen; and gave its own volume of carbonic acid. Hence the inflammable portion of the gas was *carburetted hydrogen*. From the experiments of Mr. Dalton on the gas from stagnant water, and my own obtained by distilling pit-coal, the fire-damp appears to differ very little from both these gasses.

"It was desirable, however, to repeat the analysis of fire-damp, less adulterated with common air; and for this purpose a quantity was collected (as it issued through water on the floor of a mine) in an inverted bottle, which was well corked, and tied over with a bladder. Happening to pass through Newcastle last spring, I carried this gas with me to Edinburgh; and, having no opportunity of making experiments upon it there, my friend Dr. Thomson was so good as to undertake its analysis, and to furnish me with the following results.

"From the action of nitrous gas and lime-water, the gas

appeared by Dr. Thomson's experiments, to contain in 100 measures,

63.0 inflammable gas
6.5 oxygen
25.5 azote
5.0 carbonic acid

100.0."

Notwithstanding all the above-mentioned facts, experiments, and observations, the real origin of the gasses which produce the damps is by no means thoroughly understood. Indeed the origin of the carbonic acid which produces the

calcareous stones and other minerals; also that the action of heat easily extricates that gas from the above-mentioned minerals; so that whenever any fermentation, or any heat arising from various causes, happens to act upon such minerals, the extrication of carbonic acid is a natural consequence. But the origin of the hydrogen gas is not equally clear. It was formerly a prevailing opinion, that the inflammable gas was produced by the action of pyrites upon

water, which produces abundance of that gas. But if the hydrogen were produced by the action of pyrites upon water, a quantity of sulphur would be naturally contained in the gas, which does not appear to be the case from the above mentioned experiments of Drs. Henry and Thomson, who expressly mention their not having found any sulphuretted hydrogen in the fire-damp which they examined.

If we consider the various successive strata of different materials which almost every excavation, and especially coal and metallic mines, exhibit to our view, a much more rational mode of accounting for the production of the inflammable gas perhaps would be, by attributing the decomposition of water, and the consequent extrication of the gas, to the agency of electricity, agreeably to the phenomena of that branch of it which is at present most advantageously cultivated under the name of *Galvanic Electricity*; which see.

Having thus stated every thing which seemed to be of importance with respect to the damps, which have infested from time immemorial, and do actually continue to infest mines of almost every kind; we shall close this article with a short account of two other, much less authentic, or much less known, kinds of damp. The account (which is contained in the Philosophical Transactions, as given by the same Mr. Jeffroy, whom we mentioned above) is as follows:

"They call the third sort the *pease-bloom damp*, because, as they say, it smells like pease-bloom. They tell me it always comes in the summer-time; and those grooves are not free which are never troubled with any other sort of damps. I never heard that it was mortal; the scent, perhaps, freeing them from the danger of a surprise; but by reason of it many good grooves lie idle at the best and most profitable time of the year, when the subterraneous waters are the lowest. They fancy it proceeds from the multitude of red-trefoil flowers, by them called *honey-suckles*, with which the lime-stone meadows in the Peak do much abound. The fourth damp is the strangest and most pestilential of any, if all be true which is said concerning it. Those who pretend to have seen it (for it is visible) describe it thus. In the highest part of the roof of those passages which branch

out from the main groove, they often see a round thing hanging, about the bigness of a foot-ball, covered with a skin of the thickness and colour of a cob-web. This, they say, if it is broke by any accident, as the splinter of a stone, or the like, disperleth itself immediately, and suffocates all the company. Therefore, to prevent casualties, as soon as they have espied it, they have a way, by the help of a stick

and long rope, of breaking it at a distance; which done, they purify the place well with fire, before they dare enter it again. I dare not avouch the truth of this story in all its circumstances, because the proof of it is impossible, since they say it kills all that are likely to bear witness to the particulars; neither do I deny but such a thing may have been seen hanging on the roof, since I have heard many affirm it."

Dendrometer

DENDROMETER, (from *δένδρον*, a tree, and *μετρέω*, I measure,) an instrument for measuring trees. The first instrument for the purpose of measuring the trunk, the branches, and the height of a tree, without actually touching the tree, was contrived, not many years ago, by Messrs. Duncombe and Whittel, who called it the *dendrometer*, and obtained a patent for the exclusive sale of it. Since this instrument serves to measure trees from a determinate distance, other instruments, contrived subsequent to it, for the purpose of measuring the sizes as well as the distances of objects in general, though not particularly intended for the mensuration of trees, have likewise been called *dendrometers*. The principle of every one of those instruments is, that a part of the instrument forms a base of known dimensions, and the angle at each extremity of this base being measured with great accuracy, the distance of the object may be obtained by means of an easy calculation, or from a table. The distance being thus ascertained, the size of the object will afterwards be easily determined from the angle which it is found to subtend. We shall now in the first place describe Messrs. Duncombe and Whittel's original dendrometer; secondly, we shall describe another instrument lately contrived for the purpose of measuring trees but by immediate contact; and shall, lastly, give a general idea of the other instruments for measuring distances, &c. which have likewise obtained the name of *dendrometers*.

"Messrs. Duncombe and Whittel's dendrometer consists of a semicircle A, (*Plate VI. Surveying, fig. 7.*) divided into two quadrants, and graduated from the middle. Upon the diameter B, there hangs a plummet, L, for fixing the instrument in a

vertical position. There is also a chord, D, parallel to the diameter, and a radius, E, passing at right angles through the diameter and chord. From a point on the radius, hangs an altimeter C, between the chord and diameter, to which is affixed a small semicircle G, and a screw to confine it in any position. The altimeter, which is contrived to form the same angle with the radius of the instrument as the tree forms with the horizon, is divided from its centre both ways into 40 equal parts; and these parts are again subdivided into halves and quarters. Upon the small semicircle, G, on which is accounted the quantity of the angle made by the altimeter and radius, are expressed degrees from 60 to 120; being 30 on each quadrant. The radius is numbered with the same scale of divisions as the altimeter. There is also a nonius to the small semicircle, which shews the quantity of an angle to every five minutes. On the back of this instrument the stock M, (*fig. 8.*) of the sliding piece is confined to the axis N which moves concentrically parallel to the elevation index, F, (*fig. 7.*) on the opposite side, to which it is affixed. This index is numbered by a scale of equal divisions with the altimeter and radius. At the end of the index is a nonius, by which the angles of elevation above or of depression below the horizon, measured upon the semicircle of the instrument, are determined to every five minutes. There is also a groove in the radius, that slides across the axis by means of a screw, I, working between the chord and semicircle of the instrument; and this screw is turned by the key O. Upon the stock, M, (*fig. 8.*) is a sliding piece, P, that always acts at right-angles with the altimeter, by means of a groove in the latter. To the shank of the sliding piece is affixed a moveable limb, Q, which

forms the same angle with the altimeter as the bough forms with the body, or trunk, of the tree. This limb may be of any convenient length, divided into equal parts of the same scale with all the foregoing divisions."

"At the extremity of the fixed axis, on a centre, an index, R, with telescopic sights, works horizontally upon the moveable limb of the sliding piece. Upon this horizontal index, R, may be fixed a small quadrant, T, described with any convenient radius from the centre, on which the index moves, and divided into 90° ; beginning at a right line drawn from the centre at right angles with the fiducial edge of the said index; and upon the extremity of the axis is a nonius, whereby to determine the quantity of an angle upon the quadrant to every five minutes. There are also two small circular arches, S, S, serving to keep the sights in a parallel position, each containing an equal number of degrees. Upon these arches is measured the angle, subtending a side equal to the difference of the altitudes of the observed objects, above the plane of the horizon, and whose base is the nearest distance between the perpendiculars, in which those objects are situated. The *dendrometer* is fitted to a theodolite, and may be used either with or without it, as occasion requires."

"The principal use of this instrument is for measuring the length and diameter of any tree, perpendicular, or oblique, to an horizontal plane, or in any situation of the plane on which it rests, or of any figure, whether regular or irregular, and also the length and diameter of the boughs, by mere inspection; and the inventors of it have calculated tables, annexed to their account of the instrument itself, by the help of which the quantity of timber in any tree is obtained without calculation, or the use of the sliding rule.

"The instrument is rectified by setting it in a perpendicular position, by means of the plummet, and screwing it to the staff; then the altimeter is placed in the exact position of the tree, whether perpendicular, reclining, or inclining, and is screwed fast. If the tree stands on level ground, the horizontal distance from the tree to the axis of the instrument is measured with a tape line, and the radius is moved with the key, till that distance be cut upon it by the inside of the diameter: but if the ground be slanting, the distance from the tree to the instrument is measured, and the elevation index is moved, till the point of the tree, from which the distance was measured, is seen through the sights, and there screwed fast; and the radius is moved backwards or forwards with the key, till this distance is cut upon the elevation index by the perpendicular line of the altimeter; and the horizontal line will be marked upon the radius by the inside of the diameter. In order to obtain the length of the tree, the elevation index is first moved downwards, till the bottom of the tree, cut by the horizontal wires, is observed through the sights, and the feet and inches marked by the index upon the altimeter below the point of sight, or horizontal line, are noted down: then the index is moved upwards, till the part which you would measure, cut by the horizontal wires, is seen, and the feet and inches marked on the altimeter, above the point of sight, are noted: these two quantities added together, give the exact length of the tree, which is inserted in a field-book. For the girth of the tree, the circumference in that part where the horizontal distance was taken, is measured with the tape line; and a sixth part of this circumference is added to the distance on the radius, which was before cut by the inside of the diameter, because the tape-line, in taking the distance, cannot be applied to the centre of the body of the tree; then the elevation index is lowered to that part of the tree, of which the diameter is to be taken, and is screwed

fast. Set the moveable limb of the sliding-piece quite straight, and the edge of the horizontal index upon the first division of it. Turn the whole instrument about to the left hand, till you see, through the sights, the left side of the tree cut exactly by the perpendicular wires: then the instrument being fixed, move the sights only upon the sliding-piece, till you see the right side of the tree, cut also by the perpendicular wires, and you will find the true diameter, marked by the horizontal index upon the sliding-piece, which is to be entered in a distinct column of the field-book.

"For the boughs: let the distance on the radius be now reduced to its former quantity, and the elevation index moved upwards, till the bough is seen through the sights, and screwed fast. Set the moveable part of the sliding piece in a position parallel to the bough, and the edge of the horizontal index on the first division of it. Turn the whole instrument about, till you see, through the sights, the shoot of the bough, close to the trunk cut by the perpendicular wires; then move the sights, till you see the other end of the bough cut by the said wires, and note the feet and inches marked by the horizontal index on the moveable limb of the sliding piece, which will give the true length of the bough to be inserted in the field-book. And the girth of the bough may be obtained, by directing the sights to that part of it, whose girth is desired; then by moving the elevation index downwards, till you see the under-side of the bough cut by the horizontal wires, and there noting the feet and inches marked by the said index on the altimeter; after which let the elevation index be moved upwards, till the upper side of the bough, cut by the horizontal wires, is seen; the feet and inches marked upon the altimeter are to be noted as before: the former quantity subtracted from the latter, will give the true diameter of the bough, which is entered in the field-book. The true solidity, both of the body of the tree, and of the boughs, may be found from the diameter and length, in tables calculated for this purpose.

"The dendrometer, fitted to a theodolite, may be applied to the measuring of heights and distances of objects accessible or inaccessible, whether situated in planes parallel, or oblique, to the plane in which the instrument is placed. It may be also used for taking all angles, whether vertical, horizontal, or oblique, in any position of the planes in which they are formed; and thus for facilitating the practical operations of engineering, land-surveying, leveling, mining, &c. and for performing the various cases of plane trigonometry, without calculation; of which the inventors have subjoined a variety of examples to their account of the instrument in their treatise upon the *Dendrometer*."

Notwithstanding the ostensible extensive application of this instrument, it does not appear that the use of it has been generally adopted, which may be principally attributed to its complicated construction.

The 25th volume of the Transactions of the Society for the encouragement of Arts, Manufactures, and Commerce, contains a very useful and simple machine for the measurement of the girths of trees, to which the inventor, Mr. James Broad, gives the name of *Gauge*, or *Measure for Timber*, but which in fact is a dendrometer in the strict sense of the word, and it therefore deserves a place in the present article. This instrument is represented in *Plate III. Surveying*, fig. 9. *a a, a a*, Mr. Broad says, are two long pieces of well-seasoned wood, joined near the middle by a pin, *b*, going through them, forming an axis on which they move: *c, c*, are two pieces of brass screwed near the upper ends, on the sides opposite to each other, and projecting over to form the measuring points: *d*, is the index fastened to one of the pieces of wood at *e*, and moving freely under a small bar at *f*:

g, g, are screws with nuts, placed in the middle of the long slits of the two arms, to wedge them open, whereby the vibration is destroyed, and the arms, though light, are rendered stiff: *b, b, b, b*, are screws and nuts, to prevent the arms from splitting. With respect to the general construction, use, and improvements that may be made to it, Mr. Broad expresses himself in the following manner.

"The instrument is composed of two straight pieces of well-seasoned deal, about 13 feet long, joined together by a pin going through them, on which they are moveable; but neither the length nor thickness is of any particular consequence, as by following the directions hereafter given, they may be made of any size. A little way from the large end is a brass limb, I call the index, on which are engraven figures denoting the quarter-girth in feet and inches. To use this instrument, it is only necessary to take hold of the large end, and apply the other to that part of the tree where you wish to know the girth, opening it so wide as just to touch at the same time both sides of it, without straining it, keeping the graduated side of the index uppermost, on which the greater girth will be shewn, after allowing for the bark, by the inner edge of the brass on the right-hand leg. An operation so easy and simple, that a person of the meanest capacity might measure a great number of trees in a day.

"For taking the height of a tree, I would recommend deal rods of seven feet long, made so as to fit into ferrils at the end of each other, tapering all the way in the same manner as a fishing-rod. A set of five of them with feet marked on them, would enable a man quickly to measure a tree of more than 40 feet high, as he would be able to reach himself about seven feet.

"The improvements it is capable of, are, making a joint in the arch or scale, to enable it to shut up, (when the legs are closed) towards the centre, which would make it easier to carry. Secondly, as it sometimes happens that standing timber is sold without any allowance for bark, and at other times with a less allowance than one inch in 13, two other scales on the index might be added in such cases, one without any allowance, and the other to allow as might be agreed on. I would have added these, but thought the society would rather see it in the state in which it has been tried on a large survey, as any artist can with great ease add whatever scale he pleases. The present scale allows one inch in 13 for bark, and is calculated on the following data. The diameter of a circle, whose quarter-circumference is 26 inches, is 33.96 inches. The diameter of a circle, whose quarter-girth is $6\frac{1}{2}$ inches, is 8.27 inches. To graduate the scale, the instrument is opened so as to take in at the small end between the touching points 8.27 inches, and a mark is made on the arch to denote 6 inches quarter-girth; it is then opened so as to take in 33.96 inches, and another mark is then made on the arch, to denote 2 feet quarter-girth; (these marks are made close to the inner edge of the brass on the right-hand limb;) the space between them is then divided into 18 parts, which represent inches, and are again divided into halves, for half-inches; if any notice is to be taken of quarter-inches, the eye will easily make a farther division."

The methods of determining the distances and sizes of objects placed at a distance from the observer, depend entirely upon trigonometrical principles; and those methods for effecting that purpose, which seem to differ from trigonometrical principles, will upon examination be found to be nothing more than trigonometrical methods abridged or disguised. The general principle upon which all the operations of plane trigonometry depend, is to find out three of the

six parts of a triangle, when the other three are known; (the six parts being the three sides and the three angles;) excepting, however, when the three angles are given; for in this case the proportion only of the three sides may be found; but not their actual lengths.

When an inaccessible distance is to be determined by trigonometry, the method is to measure a line or base upon any convenient place, and to observe the angles which the imaginary lines, supposed to be drawn from the extremities of that base line to a point or object at the extremity of the distance sought, make with the base; for in that case we have two angles, and one side of a triangle, whence we find by calculation the lengths of the other sides, one of which is the distance sought. If an object of any known dimensions be situated at the extremity of the distance sought, that distance may then be determined without the necessity of assuming a base line upon the place of observation; for in that case, the object itself will be supposed to form the base of an isosceles, or of a right-angled triangle; and it will be only necessary to measure the angle which that object subtends at the place of observation. The distance of an object being known, the size of the object may be easily determined by only measuring the angle which it subtends. See TRIGONOMETRY.

Now the dendrometers for measuring distances from a single station, are so constructed as to have a line of a determinate length within themselves, which serves as a base line, and two divided circular arches, or some other contrivance by which the angle which the direction of a distant object makes with that base line at each extremity of it, may be measured. But as such instruments cannot be made of an inconvenient large size, the base line which they contain is but short, and the error of the calculation is greater when the base line is shorter, and *vice versa*; whence such instruments seldom furnish a result sufficiently exact, at least for certain purposes.

The most complete instruments of this kind are furnished with two or more speculums, (somewhat in the manner of Hadley's quadrant,) for measuring the difference of the angles at once. Upon this plan several instruments have been contrived and offered to the public by various writers. One of the most promising, though not the most compact, is described in "Gower's Supplement to the Practical Seaman-ship." But as we are not acquainted with the construction of any instrument of this kind, that is quite free from strong objections, we shall only subjoin a general idea of the principles upon which such an instrument may be constructed; for the use of those persons who may be desirous of employing their thoughts upon the possible improvements of that construction.

The following plans are suggested by William Pitt, esq., in the second volume of the Repertory of Arts; which, he says, may perhaps be otherwise varied and improved.

"O, (fig. 10.) is the object, whose distance is required. ABCDE is the instrument *in plano*; BC a telescope placed exactly parallel to the side AE. CE an arch of a circle whose centre is at A, accurately divided from E, in degrees, &c. AD is an index, moveable on the centre A, with a nonius at the end D, graduated to apply to the divisions of the arch; also with a telescope, to enable the observer to discriminate the object, or any particular part, or side, thereof, the more accurately. The whole should be mounted on three legs in the manner of a plane-table or theodolite, and furnished with spirit-levels, to adjust it to an horizontal position. The instrument being placed in such position, the telescope BC must be brought upon the object O, or rather upon some particular point or side thereof;

when, being there fastened, the index AD must be moved, till its telescope exactly strikes the same point of the object; then the divisions on the arch ED , mark out the angle DAE , which will be exactly equal to the angle BOA . And the side BA being already known, the distance BO , or AO , may be easily determined two different ways; viz. 1st, by supposing the triangle BOA to be an isosceles triangle; or, 2dly, by supposing the triangle ABO right-angled at B . The accuracy of such an instrument does, *ceteris paribus*, much depend upon the length of the line AB .

"The construction of a similar instrument, on the principles of Hadley's quadrant, for naval observations, would also doubtless be an acceptable object in navigation, by enabling the mariner to ascertain the distances of ships, capes, and other objects, at a single observation; and that perhaps with greater accuracy than can be done by any method now in use.

"For this purpose, the following construction is proposed. $ABCD$, (*fig. 11.*) represents the instrument *in plano*. O is the object whose distance is required. At A , at C , at D , and at 3 , are to be fixed speculums, properly framed and fitted; that at 3 having only its lower part quicksilvered, the upper part being left transparent, to view the object; the speculum at A being fixed obliquely, so that a line $A1$, drawn perpendicular to its surface, may bisect the angle BAC in equal parts; that at C being perpendicular to the line $C2$; those at E , and at 3 , being perpendicular to the index $E3$; and that at E being furnished with a sight. The arch DC is to be divided from D , and the

motion of the index is to be measured as before by a nonius. And as the length of the line AE would tend to the perfection of the instrument, it may be constructed so as to fold up in the middle, on the line $C2$, into less compass when not in use. The instrument may be adjusted for use, by holding up a staff at a distance, whose length is exactly equal to the line AE .

"To make an observation by this instrument, it being previously properly adjusted, the eye is to be applied at the sight in the speculum E , and the face turned towards the object; when the object being received on the speculum A , is reflected into that at C , and again into that at E , and that at 3 on the index; the index being then moved till the reflected object, in the speculum at 3 , exactly coincides with the real object in the transparent part of the glass. Then the divisions on the arch $D3$, subdivided by the nonius, will measure the angle $DE3 = AOE$; from which the distance of O may be determined as before."

When a straight line of at least 10 or 20 feet, may be measured at the station, where the observer is situated, and in the direction of a distant object; the size and distance of that object may be determined by the use of a most simple instrument; namely, a telescope furnished with a micrometer, and thus trees and other objects may be measured in a manner extremely commodious and sufficiently accurate. The problems necessary for this purpose, as given by Mr. Cavallo in the description of his "Telestial Mother-of-Pearl Micrometer," will be found under the article MICROMETER.

Derby

DERBY, the county and principal town in Derbyshire, England, occupies a flat tract of land on the banks of the river Derwent, the waters of which prove eminently serviceable to the manufactures of this place. Derby was a place of repeated conflicts in the early periods of English history. In the year 874, it was occupied by the forces of Halfden, a Danish chief, whose head quarters were then at Rependune, now Repton. In 918, the Danes were still its masters; but the same year they were attacked by surprise, and completely routed by the heroic Ethelfleda, daughter of king Alfred, and princess of the Mercians. In a few years the Danes regained possession; but were again expelled in 942 by king Edmund, and about the same time dispossessed of all the principal towns in the neighbouring counties of Lincoln, Stafford, Nottingham, and Leicester. That Derby about this period was a place of great importance, is evident from its being mentioned in Domesday-book as a royal borough of Edward the Confessor, containing fourteen mills for grinding corn, and 243 burgesses, forty-one of whom held twenty-four plough-gates of taxed land. The annual rent then paid was 24*l*. When William the Conqueror obtained the crown, he gave Derby, with a great rent-roll, to his illegitimate son, William Peverell. It was afterwards granted by Henry I. to the earl of Chester, and made a corporate town; but its charter has been altered at various periods. It obtained additional privileges from

Henry I. and II. Richard I. and John; in whose time the burgesses were indebted to the exchequer 56 marks, for the confirmation of their liberties. In the same reign, they were likewise returned debtors in sixty marks, and two pal-freys, for holding the town of Derby at the usual fee-farm; and 10*l*. increase for all services, and having such a charter as the burgesses of Nottingham. A grant was obtained from Richard I., by which Jews were prohibited from residing in the town. In the reign of Edward III. the corporation was deprived of its liberties, and summoned into one of the king's courts, to answer "By what authority they demanded toll, yet paid none? Why they claimed the exclusive privilege of dyeing cloth, and prohibiting cloths to be dyed in every other place within ten leagues, except Nottingham? They were also to declare by what right they chose a bailiff yearly; and why they kept a fair on Thursday and Friday in Whitsun-week, and another of seventeen days at the time of the festival of St James: to explain by what authority they had a coroner; why the burgesses should not be sued out of their own borough; and wherefore they held weekly markets on Sunday, Monday, Wednesday, and Friday?" Some mutilated charters were produced in answer to these requisitions; but the liberties of the town were not restored till the inhabitants had paid a fine of 40 marks, and consented to pay an increase of rent. In the year 1611, James I. granted a new charter, confirming the privileges bestowed in former reigns, and investing the corporation with

additional liberties. By this charter the bailiffs, recorder, and town-clerk, or any three of them, were privileged to hold a court of record on every second Tuesday; to have the sole return of writs, keep a quarterly session, two courts-leet, and six annual fairs; to be toll-free throughout the kingdom; and receive toll from all, except the duchy of Lancaster, which was to pay only half the sums charged on the inhabitants of other places. In 1638, it was determined, that the authority of the two bailiffs should be vested in one person, to be chosen annually, and to be called mayor. The then bailiffs, Henry Millor, and John Hope, were the first that held that title. In 1680, the ancient charter was surrendered to Charles II., and a new one (the present) obtained at the expence of nearly 400*l*. The corporation now consists of a mayor, nine aldermen, fourteen brethren, (out of whom the aldermen are elected) fourteen common-council men, a recorder, a high-steward, and a town-clerk. The privilege of returning members to parliament is possessed by the freemen and sworn burgesses; about 700 in number. In the reign of queen Mary, a woman was burnt in this town for maintaining that the sacrament was only a memorial or representation of the body and blood of Christ, and that the elements were merely bread and wine. In 1592, the plague ravaged this town: and in 1665, when London was nearly depopulated by that dreadful calamity, it again broke out at Derby, and proved so fatal, that the country people refused to bring their commodities to the market-place. The inhabitants, to prevent a famine, raised a pile of stones, which received the name of *Headless-Cross*, in an open space without the town. Here the market people placed their provisions, and retired, till the buyer, who was not permitted to touch any article, till purchased, had concluded his bargain, and deposited his money in a vessel filled with vinegar. In the rebellion of 1745, Derby was distinguished as the farthest place in England to which the pretender's army reached. Their coming being expected, proper measures had been taken for the safety of the town; and nearly 600 men raised by subscription, besides 150 levied and maintained at the sole expence of the duke of Devonshire.

The situation of Derby, on the banks of the Derwent, renders it, as before observed, extremely favourable for the institution, and process, of manufactures which require the aid of water; and various works have been established in the town, or its immediate vicinity. Their success, however, has been greatly promoted by the judicious application of machinery; and mills on the most improved construction have been erected for various purposes. Those belonging to Messrs. Strutt, for the manufacture of cotton, are particularly ingenious; and the facility attained by them in working stockings, figured waistcoat-pieces, and many other articles, has eminently contributed to the extension of this branch of business. One of these mills is remarkable for its floors being all constructed on brick arches, and paved with brick, whereby it is rendered absolutely indestructible by fire. This building is six stories high, 115 feet long, and 30 feet wide; it was erected in 1793, and was the first fire-proof mill ever built.

Besides the cotton factories, the manufactures most celebrated in Derby, are those of silk, porcelain, and ornaments, &c. of Derbyshire spar and marble. The manufacture of silk is carried on to a great extent, and the number of men, women, and children employed in it is upwards of 1000. The work is chiefly performed by means of machines, or mills, of various size, and different construction. The original mill, called the *silk-mill*, by way of pre-eminence, being the first and largest of its kind ever erected in England, stands on

an island on the river Derwent. Its history is remarkable, as it exemplifies the power of genius, and the vast influence which the enterprises of an individual has on the commerce of a country.

The extensive fabric which contains the machinery, stands upon huge piles of oak, doubly planked, and covered with stone-work, on which are turned thirteen stone arches, that sustain the walls. Its whole length is 110 feet, its breadth 39, and its height 55½. It contains five stories, beside the under works, and is lighted by 468 windows. In the three upper stories, are the Italian winding engines, which are placed regularly across the apartments, and furnished with many thousand swifts and spindles, and engines for working them. In the two lower rooms are the spinning and twist mills, which are all of a circular form, and are turned by upright shafts passing through their centres, and communicating with shafts from the water-wheel. Their diameter is between twelve and thirteen feet, and their height nineteen feet eight inches. The spinning mills are eight in number, and give motion to upwards of 25,000 reel bobbins, and nearly 3000 star-wheels belonging to the reels. Each of the four twist mills contains four rounds of spindles, 389 of which are connected with each mill, as well as numerous reels, bobbins, star-wheels, &c. The whole of this elaborate machine, for one only it is, though distributed through five large apartments, is put in motion by a single water-wheel, twenty-three feet in diameter, situated on the west side of the building. The whole number of wheels is about 14,000. All the operations are performed here, from winding the raw silk, to organizing or preparing it for the weavers. The raw-silk is chiefly brought in skains or hanks from China and Piedmont; that produced in the former country is perfectly white, but the produce of the latter is of a light yellow. The skain is first placed on an hexagonal wheel, or *swift*, and the filaments which compose it are regularly wound off upon a small cylindrical block of wood, or *bobbin*. To wind a single skain is the work of five or six days, though the machine is kept in motion ten hours daily; so astonishingly fine are the filaments of which it is formed. In this part of the process, many children are employed, whose nimble fingers are kept in continual exercise by tying the threads that break, and removing the burs and uneven part, some of which are the cases which the silk-worm fabricates for its own grave, or rather for its dormitory, while nature prepares it for a new mode of existence. The silk thus wound upon the bobbin, is afterwards twisted by other parts of the machinery, and is then sent to the *doublers*, who are chiefly women, stationed in a detached building, which stands on the same island, on piles like the silk-mill; and though not half so broad, is nearly thirty feet longer. Here four, seven, or ten of the threads are united into one, according to the uses for which they are designed; the fine kind going to the stocking weaver; the others to the manufacturers of waistcoat-pieces, &c.

The manufacture of porcelain was originally established at Derby about the year 1750, by the late ingenious Mr. Duesbury; but the most considerable improvements have been effected since his decease, through the judicious methods employed in preparing the paste, and increasing the beauty of the decorations. The ware itself is not of equal fineness with the French and Saxon; though its workmanship and ornaments are far superior. The paintings are, in general, rich and well executed, and the gilding and burnishing exceedingly beautiful. The body of the semi-vitreous ware, called porcelain, is fine white clay, combined with different proportions of fluxing matter. The best kind is absolutely infusible, and takes for its glaze a vitreous sub-

stance, without a particle of lead. When the paste is duly prepared, by grinding and other operations, it is conveyed to the workman, whose dexterity produces a variety of beautiful forms from the shapeless mass delivered to him. Round vessels are usually made by a man called a *thrower*, who works them on a circular block, which moves horizontally on a vertical spindle. From him they pass to the lathe, and are reduced to their proper thickness and form at the end of an horizontal spindle. Afterwards they are *finished*, and *handled* if necessary by other persons, and are then conveyed to a stove where they remain till the moisture is entirely evaporated, when they become fit for baking. Oval vessels, such as tureens, tea-pots, &c. assume their form by being *pressed* into moulds of plaster, or gypsum, by hand. The *jaggars*, or cases, in which the articles are burnt, are various in size and dimensions. These are set in the kiln or oven, one upon the other, and when piled up nearly to the top, have some appearance of piles of cheese. When the kiln is full, it is carefully closed, and the ware baked by the admission of heat through horizontal and vertical flues; this is the first baking, and the porcelain in this state is vulgarly called biscuit. It is then dipped in glaze of about the consistence of cream, and carried to the glaze kiln, where it is again baked, but in a less degree of heat than before. The ware is now delivered to the painters, who, with colour prepared from mineral bodies, ornament it with landscapes or figures, according to the required patterns. After this process, it is again conveyed to the kiln, and the colours vitrified, in order to fix and give them a proper degree of lustre. Every coat, or layer of colour, requires a fresh burning; once or twice is sufficient for the ornaments of the common porcelain, but the more elaborate decorations render it necessary for the colours to be laid on, and undergo the action of fire several times, before they obtain their full effect. This completes the process of those articles that have no gold in their pattern; but where this addition is wanted, they are pencilled with a mixture of oil and gold dissolved, or thrown down by quicksilver aided by heat, and once more committed to the kiln; here the gold reassumes solidity, but comes out with a dull surface, which is quickly rendered brilliant by rubbing with blood-stones, and other polishing substances. The porcelain is now ready for use, but the latter part of the process requires considerable care, as the gold, when not sufficiently burnt, will separate in thin flakes, and when over-fired, will not receive a proper polish. The highest finished ware in this manufactory is frequently returned to the enamel kiln, where the colours are fluxed six or seven times; the best only are here finished for sale. The making of biscuit figures, or white ware, is peculiar to this manufactory; and the pieces are supposed to be equal in beauty and delicacy to any of a similar kind made in Europe. Here the lathe is of no use, the figures being all cast in moulds of plaster or gypsum, into which the materials are poured, having previously been reduced to a liquid of the consistence and appearance of thick cream. The water contained in the mixture is quickly absorbed by the plaster, and the paste becomes sufficiently hard and tenacious to part freely from the mould. The various parts of the figures, as the head, arms, legs, &c. are cast in separate moulds, and when dried and repaired, are joined by a paste of the same kind, but thinner than the former. The articles are then sent to the kiln, and after undergoing a regular and continued heat, come out extremely white and delicate.

The original silk-mill, erected by Mr. Crochet, and now called the old shop, was afterwards converted into a cotton factory, but is at present in the occupation of Messrs. Brown

and son, who employ it for cutting and polishing marble, and manufacturing the Derbyshire fluor spar, or blue John, and gypsum, into a variety of beautiful ornaments, as urns, vases, columns, obelisks, &c. The machinery applied to execute these purposes is of very ingenious construction; and the lathes are so contrived, by the assistance of a reverse motion, that they can readily be made to revolve either slower or faster, as the design or quantity of the substance under manufacture may require. They may likewise be stopped at pleasure, without impeding the motion of any other part of the works. When the blue John is to be made into a vase, or any other ornamental form that renders the use of the lathe necessary, it is carved with a mallet and chisel, into a rude resemblance of the object intended to be produced, and being afterwards strongly cemented to a plug or chock, is screwed upon the lathe. A slow motion is then given to the work, and a bar of steel about two feet long, and half an inch square, properly tempered, and pointed at each end, is applied to the fluor, on which water is continually dropping to keep the tool cold, preserve it from friction, and enable it more readily to reduce the substance upon which it acts. As the surface becomes smoother, the tool is applied with more freedom, and the motion of the lathe accelerated, till the fluor has assumed its destined form. When the turning is completed, pieces of grit-stone, of different degrees of fineness, are applied with water to bring the article to a proper ground for polishing with fine emery, tripoli, and putty, or calx of tin. These means are continued till the fluor is incapable of receiving a higher degree of polish; which is known when water thrown on it will no longer increase its lustre. The advantage of the lathe set in motion by water over those worked by the foot, is said to be particularly conspicuous in forming hollow vases, or articles of equal delicacy. By the use of the foot-lathe the fluor was frequently broken, and without extreme care, its laminated texture always disturbed; but the greater steadiness given to the machinery by the water-wheel, operates as an effectual preservation from these inconveniences. The great ease with which a slow or quick motion can be produced by the use of the water lathe, is also an additional advantage, and tends considerably to increase the elegance of the ornaments. The same wheel which gives motion to the lathes for manufacturing the fluor-spar, &c. is likewise applied to work the machinery for sawing and polishing marble. On the vibrating poles to which the cranks are fixed are sliding boxes, containing sets of saws, which are nothing more than thin plates of soft iron, that drop as they cut the marble. These are supplied with sand and water; and being moveable with screws, may be arranged at different distances, so that the slabs may be cut of any thickness. A set of saws consists of a different number of plates, so that the block to which they are applied may be separated at one process into as many slabs as may be thought necessary. The slabs thus sawn, are taken to the polishing bed, which has four wheels that move on a gangway with a very slow motion given to it by a worm and a crank. One of the slabs being fixed on this bed, another is fastened above it to an arm attached to a vibrating pole, that works with a quick motion in a transverse direction. The slabs thus moving in contact with each other, and being supplied with sand and water, soon acquire a level surface, when finer materials are employed to increase their smoothness, and give them a higher polish.

Derby is divided into five parishes, each of which has a church. The principal ornament of the town is All-Saints church: yet, respectable as it is, it displays a remarkable instance of architectural incongruity. The tower was

erected in the reign of Henry VIII., and its upper part is richly ornamented with tracery, crockets, high pinnacles, and battlements; but the body is Grecian, and the interior is particularly light and spacious. The roof is supported by five columns on each side. The design of the body of the church was executed by Gibbs, the ingenious architect of St. Martin's in the Fields, London. The money for building it was chiefly procured through the indefatigable exertions of the then minister, Dr. Michael Hutchinson, whose zeal and success in this work are recorded on a tablet to his memory, placed against the south wall within the church. On the south side of the chancel is the monument room of the Cavendishes; and many of that illustrious family are buried in the vault beneath. In this repository is a splendid mural monument to the memory of the celebrated countess of Shrewsbury; it was constructed in her life-time, and under her inspection. Among other monuments deserving of notice, is one to the memory of William, earl of Devonshire, who died in 1628, and Christian, his countess. Another neat monument, by Nollekins, displays the medallion and arms of William, earl of Besborough, who died in 1793; and on a mural monument, by Rysbrach, to the memory of Caroline, countess of Besborough, who died in 1760, is a well executed figure of that lady. Against the wall, on the north side of the church, is a curious memorial of Richard Croshaw, who was the son of a poor sailor in this town, and went to London in a leathern doublet to seek his fortune: possessing industry and perseverance, his endeavours proved successful; and having attained considerable affluence, he bequeathed upwards of 4000*l.* to the corporation of Derby, for the maintenance of lecturers, the relief of the poor, and other benevolent purposes. He died in 1631. The other four churches of this town are respectively dedicated to St. Alkmund, St. Peter, St. Werburgh, and St. Michael. The first of these is supposed to have been founded at the beginning of the ninth century, in honour of Alkmund (son of Alured, the deposed king of Northumberland) who was slain in battle while endeavouring to reinstate his father.

The principal public buildings in Derby are a county hall, a town hall, a county gaol, an elegant assembly room, and a theatre. The county hall, which is a large but heavy building of free-stone, was finished in the year 1660. The town hall, built by the corporation in 1730, is a handsome structure. The county gaol was erected about 1736, at the expence of the county, aided by a donation of 400*l.* from the duke of Devonshire: it is situated on the east side of the town, near the upper end of Friar gate, and is a very respectable building, well adapted for the purpose of its destination: the front is from an excellent design, displaying solidity and strength, without that affectation of incongruous ornament so frequently exhibited in modern buildings of similar character. The assembly room is of stone, and is situated on the north-east side of the market place: the foundation was laid in 1763; but the edifice was not completed till 1774. The theatre stands in Bold lane, is built of brick, and was erected in 1773.

Derby is a very improving and populous place; and though the buildings have been continually increasing for the last twenty years, they are yet insufficient for the convenience of the inhabitants. Fresh ground is frequently broken up for new houses, which are mostly let before they are completed: the number of houses, as ascertained by the late act, was 2,144. that of the inhabitants 10,832; but both are increasing, and there is reason to believe, will keep pace with the progressive improvements of the town, and the augmentation of its trade. Various branches of business, besides the manufactures already mentioned, are carried on to a consider-

able extent, and several new works of magnitude have lately been established. On Nun's green a bleaching-ground has been opened, in which the processes are performed according to the improved methods introduced by the advancement of chemistry: to aid the operation, a small steam-engine has been erected. A mill for slitting and rolling iron for a variety of purposes; a large furnace for smelting copper ore, with a machine for battering and rolling the copper into sheets; a red lead manufactory; a mill for making tinned-plates, &c. are also existing in this town or its immediate vicinity. Among the modern improvements of Derby, may be included the lighting and paving of the streets, and the removing of those obstructions that prevented a free passage. These purposes were effected by an act passed in 1792, which appointed commissioners with full power to levy a small rate on the inhabitants, and likewise to sell all the common land belonging to Nun's green; the sums thus produced to be applied in defraying the necessary charges. Since the above year, several of the bridges that were built across the Markeaton Brook have been removed, and three new ones, of stone, erected by subscription. An elegant bridge of three arches has likewise been built over the Derwent; and, together with the silk-mill, the weirs, and the broad expanse of the river, forms a very pleasing prospect on entering the town from the Nottingham road.

Numerous bequests for the relief of the poor have been made at different times by benevolent persons. One of the most considerable charities is the Devonshire alms-house, founded by the countess of Shrewsbury in queen Elizabeth's reign, for the support of eight men and four women: the old house was taken down about twenty years ago, and the present erected by the duke of Devonshire. Science and literature meet with great encouragement at Derby: this may, in some degree, be ascribed to the Philosophical Society established here about the year 1772, through the fostering patronage of the late Richard French, esq. and Dr. Darwin, the latter of whom for many years made this town his residence. Several book-societies have also been instituted; and to the credit of the individuals composing them, the works purchased are chiefly of a scientific and philosophical tendency.

Derby, previous to the dissolution of religious houses, contained a monastery dedicated to St. Helen, founded by Robert de Ferraris, second earl of Derby, about the middle of the twelfth century; a small Benedictine nunnery, founded soon after the former by an abbot of Derby, and dedicated to St. Mary de Pratis; a priory of Dominicans, or Black Friars, founded towards the close of the thirteenth century; and a cell of Cluniac monks, founded by Walthecof, a Saxon nobleman, dedicated to St. James, and given early in the twelfth century to the abbey of Bermondsey, in Southwark. Here were also an hospital dedicated to St. Leonard, and a maison-dieu, both instituted for the reception of lepers.

Derby is situated 126 miles N.W. from London; it has a weekly market on Friday, and seven annual fairs.

The celebrated astronomer John Flamsteed, is considered by some authors as a native of this town; an opinion which, though controverted, is favoured by the circumstance of his father residing here.

The vicinity of Derby furnishes a variety of agreeable walks, where the inhabitants may enjoy a salutary exercise, and a succession of prospects distinguished by the softer features that attend cultivation. On Windmill-hill, at a short distance from the town, a neat prospect-house has lately been erected by — Robinson, esq. from which the views over the adjacent country are very extensive. Hutton's History

of Derby, 8vo. Pilkington's History of Derbyshire, 2 vols. 8vo. Beauties of England and Wales, vol. iv.

DERBY, a township of America, in Orleans county, Vermont, on the N. line of the state, on the E. shore of lake Memphremagog.—Also, a post-town in New Haven county, Connecticut, on the point of land formed by the confluence of Naugatuck and Housatonic rivers. This town was settled in 1665, and is now divided into two parishes, and has an academy. It has a considerable trade with the West Indies, and in its vicinity are mills on the falls of Naugatuck, and iron as well as other works on Eight-mile river, that falls into the Housatonic, which is navigable for 12 miles to this town. It has 1878 inhabitants.

DERBY, or DARBY, *Upper and Lower*, are situated in Delaware county, Pennsylvania; the former containing 862, the latter 980 inhabitants; seven miles S.W. of Philadelphia.

DERBY neck. See BRONCHOCLE.

DERBY Canal is the parliamentary name of a navigable canal in the county of Derby, which was completed in the year 1794, between the Trent river at Swarkestone, and Little Eaton, with a rail-way extension thence to the collieries at Smithey-Houses, near Denby, and a branch from the same to Housley and Smalley Mills collieries. There is also a branch from the town of Derby to the Erewash canal, near Sandycroft. See CANAL.

DERBYSHIRE is a county situated nearly in the middle of England, at an equal distance from the eastern and western seas. It is encompassed by Yorkshire and Cheshire to the north, and Staffordshire, Leicestershire, and Nottinghamshire to the east, west, and south. The area is supposed to measure about 55 miles from north to south, and 38 in an opposite direction, and comprises nearly 720,640 acres of land. Of these above 500,000 are cultivated arable and pasture, whilst the remainder consists chiefly of bleak mountainous regions, and open commons. The whole county is divided into six hundreds, and contains 11 market towns, and 136 parishes. These comprehend 33,191 houses, and about 161,142 inhabitants.

The northern and southern parts of this county exhibit a striking difference and contrast in geographical features: as the former abounds with hill and vale, and the latter presents a flat surface. The higher region is denominated the High Peak, and the latter the wapentake, or Low Peak. Among the chief eminences in this district are the mountains of Ax-edge, and Kinder-scent. The former is situated near Buxton, and was calculated by Mr. Whitehurst to be about 2100 feet higher than the town of Derby, and 1000 feet above the valley in which Buxton-hall stands: the elevation of Kinder-scent, though not precisely ascertained, is supposed to be greater. The High Peak is a region of bleak barren heights, and long extended moors, interspersed with deep vallies, through which the small streams take their course. Here the scenery is in many parts romantic and sublime; though, on the whole, interior in picturesque effect to that of other mountainous countries. Beauty, indeed, is only resident in the vallies; the high ground appearing dreary and destitute of entertainment; and in many situations not a single house or tree is to be seen, to divert the eye of the traveller, or relieve the weariness that arises from the contemplation of sterility and nakedness. The Low Peak abounds with eminences of various height and extent. Brassington-Moor, Alport, near Wirksworth, and Crich-Cliff, are the most elevated, and command very extensive prospects: from Alport, on a clear day, the Wrekin in Shropshire may be distinguished. On the east side of the county there is also a high ridge of considerable extent, beginning to the south of Hardwick, and

continuing in another direction to the extremity of the county, where it enters Yorkshire. The southern part of Derbyshire is in general pleasant and well cultivated, but presents no particular variety of scenery. The mountainous part of this county is distinguished from the rest, by the greater quantity of rain which falls in it. At Chatworth, which is by no means the highest tract, about 33 inches of rain have been found to fall annually at a medium. The High Peak is peculiarly liable to violent storms, in which the rain descends in torrents, so as frequently to occasion great ravages in the lands; it is also subject to very high winds. These causes, together with the elevation of the country, render it cold, so that vegetation is backward and unkindly. Some kinds of grain will not grow in the Peak, and others seldom ripen till very late in the year. The atmosphere is, however, pure and healthful, and the higher situations are generally free from epidemic diseases, though agues and fevers sometimes prevail in the vallies. One disease is, however, endemic in these parts, and even as far south as Derby; this is the Bronchocle or Derby-neck: it is an enlargement of the glands of the throat; and is a degree of the same disease that is known in the Alps, and other mountainous tracts. It is also prevalent in some parts of Sumatra and the East Indies.

The most common soil of Derbyshire is a reddish clay, or marl; the southern district is in general composed of it, having little or no stone near the surface: but some parts of this tract are interspersed with small beds of sand or gravel; and in moist situations, land of a blackish colour, and loose texture, is sometimes met with, continuing through an extent of from 50 to 200 acres. This kind of soil is likewise found throughout the southern and middle part of the extensive tract of limestone, which lies on the north-west side of the county. Its colouring principle is iron; but its quality is very various in different situations: in some it contains much calcareous earth; in others it does not effervesce with acids. The large tract on the eastern side of the county, which extends from Stanton, Dale, and Morley, to the borders of Yorkshire, and abounds with coal, is covered with a clay of various colours, black, grey, brown, and yellow, but principally the last; and is in some places mixed with a large proportion of sand. Similar soil is also met with in the northern extremity of the county; and in some parts where gritstone is found; but in the latter situations, the land is more frequently of a black colour, and bituminous quality. In the vallies, near the banks of the larger rivers, the soil is very different from that of the adjacent parts, and has been evidently altered by the depositions from the inundations. Peat bogs exist in the north parts of the county, even on the highest mountains; and in some of them, trees have been found nearly perfect. Barley is much cultivated in many parts, but particularly in the parishes of Gresley and Repton, where the farmers are induced to grow it, by the consumption of malt in the neighbouring town of Burton, whose famous ale has acquired such extensive celebrity. The whole produce has been calculated at about 5000 quarters annually. On the eastern side of the county the land is chiefly under tillage; but the midland tracts have a mixture of pasture and arable, according to situation: the moors in this district are in a course of progressive improvement. In the High Peak the grounds are chiefly appropriated to the grazing and breeding of cattle; very little corn, besides black oats, being grown: on the more elevated parts, sheep of the smaller horned kind are fed: the mutton is excellent. Little attention has been paid to the cultivation of artificial grasses: but an uncommon species of culture, as a field crop, here practised is that of chamomile: about 200 acres are devoted to its

growth. A loamy soil is chosen for its cultivation, and, after the ground is well prepared by thorough cleanings, about the end of March, the roots of an old plantation are taken up, and divided into small slips, which are planted in rows about eighteen inches asunder, and at about the same distance in the rows. The plants are kept clean by frequent hoeing and weeding with the hand. In September the flowers are fit to gather: their perfection depends upon their being fully blown, without their having stood so long as to lose their whiteness; the flowering continues till stopped by the frosts. The gatherings are repeated as often as successions of flowers appear; but this depends very much on the season, dry open weather furnishing more successions than wet or dull weather. When the flowers are gathered, they are carefully dried, either in kilns very moderately heated, or on the floors of boarded rooms, heated by slow fires: the object is to keep the flowers white and whole, and this is best effected by drying them as slowly as possible. The produce varies from two hundred weight, or even less, to four, five, and in some few instances, six hundred weight *per* acre. The price has also varied from 2*l.* to 7*l.* *per* cwt. The plants usually stand three years, of which the first affords the smallest produce; and the second the greatest and best. When the same plants are continued beyond three years, the ground becomes foul, and the flowers weak. When dried, the flowers are packed in bags; and afterwards sold to persons in the neighbourhood, who transmit them to the druggists in London.

For the botanical character and medicinal properties of chamomile, see *ANTHEMIS*.

The inclosures of Derbyshire are very numerous, and are annually extending. Within the last twenty or twenty-five years, more than one-fourth of the county has been inclosed, and the rent in many instances nearly doubled. The southern part, and the wapentake, are almost wholly in this state; but the grounds in the High Peak are chiefly open. The former districts are tolerably well provided with timber, but in this respect the plantations of Kidleston park are unrivalled by any in the county.

The manufactures which are carried on in Derbyshire are various and extensive. With Nottinghamshire and Leicestershire, it partakes in the manufacture of stockings; with Yorkshire, in that of iron, and of woollen-cloth; and with Lancashire, in that of cotton. To these may be added the manufactures of silk and of Derbyshire spar, the latter of which may be considered as peculiar to this county. The business of hosiery is chiefly confined to the parts that border on Nottinghamshire, and to Litton, near Tideswell. The number of frames employed, including those on which silk and cotton stockings are wrought, has been calculated at about 1350. Wool is mostly manufactured in the High Peak, adjacent to Yorkshire. Cotton is manufactured in different modes, and in various parts of the county; but the principal factories are at Cromford, Belper, and Derby: in the former the cotton is prepared by the machine invented by the late sir Richard Arkwright; from sixteen to twenty machines, on the same model, are also employed in other parts of the county. The silk and spar manufactures are nearly confined to the town of Derby.

Besides the sources of labour derived from the branches of commerce above enumerated, the mines of lead, iron, calamine, and coal, afford employment to many inhabitants of this county. The lead mines constitute a considerable part of the natural riches of Derbyshire, and some of them have probably been worked through a long succession of ages: their produce was formerly of greater value than at present; as the veins become poorer, the deeper the mines are ex-

plained. Camden imagined that Derbyshire was alluded to by Pliny, where he says, "In Britain lead is found near the surface of the earth in such abundance, that a law is made to limit the quantity that shall be gotten." However this may be, we have decisive evidence that the Romans had lead works in this county, as several pigs of lead have been found with Roman inscriptions. The first of these was discovered on Cromford Moor, in the year 1777, on which the following sentence was legible: IMP. CAES. HADRIANI. AVG. MEL. LVI. That the lead mines of Derbyshire were known to the Saxons, is apparent from the mine near Castle-ton, called *Odin*, from the name of one of their deities: the same circumstance implies that it was opened previous to the introduction of Christianity into Britain. It appears also, that there were lead mines in the wapentake of Wirksworth, in the year 835; for at that period Kene-wara, abbot of Repton, granted her estate at Wirksworth to Humbert the alderman, on condition that he annually gave lead of the value of 300 shillings to archbishop Ceolnoth, for the use of Christ-Church, Canterbury. At the time of the Norman survey, the business of the lead mines was undoubtedly carried on to a considerable extent, as no less than seven mines in this county are mentioned in the Domesday book.

Veins of lead ore are distinguished on account of their various positions in the earth, by the different names of pipe, rake, and flat works. Pipe-works lie between two rocks or strata, yet seldom follow any regular inclination, but fill up fissures, the lines or branches running parallel to each other, and more or less horizontally. The veins are sometimes twenty or thirty yards wide, and sometimes not more than two inches: they most commonly have road-stone in the vicinity, either above or below. Rake, or perpendicular veins, are found in the clefts and chasms of the lime-stone; and consequently, instead of extending uniformly between the same strata, they follow the directions of the cavities, and sometimes penetrate 150 or 200 yards into the earth. The flat-works bear a great resemblance to the pipe; yet disagree in some circumstances. The principal leader or stem in the pipe is accompanied with many branches, but the flat has none; the latter spreads wider, yet seldom extends more than 100 yards. It is also found near the surface, and in the solid rock. The miners are divided in opinion whether the pipe or rake veins are most prevalent.

The greatest impediments to working the mines are foul air, and water. To relieve them from the first, a pipe or tube is generally introduced down the shaft, and extended along the roof of the gallery, to the place where the work is carried on. To remove the water many adits, or, as they are here termed, soughs, have been driven from the bottom of some neighbouring valley, and made to communicate with various works by different channels or galleries. The longest adit in Derbyshire is at Youghgrave, running from the Derwent to Alport, and called the Hilar sough. This cost upwards of 50,000*l.* It relieves a considerable number of mines, and is nearly four miles in length. Another, and one of the most considerable at Wirksworth, is called Cromford sough. This is full two miles in length, and was driven at an expence of 30,000*l.*

The annual produce of lead from the Derbyshire mines cannot be exactly ascertained, but may be estimated at an average of between 5000 and 6000 tons. The trade has been generally considered to be on the decline, as the increase of depth renders the mines more difficult to be worked, as well as more expensive; yet, from the improvements that have been made in the art of smelting, and the more effectual mode employed to relieve the mines from water, by the driving of

new levels, and the erection of some improved fire-engines, advantages have been obtained, which, to a certain extent, counterbalance the augmented expences.

Iron-stone, or oxide of iron, is found in this county in great abundance; it occurs throughout the whole district in which coal has been discovered, the Chinley hills excepted. The depth at which it lies from the surface is various, but frequently, from the great dipping of the strata, it *blosses* out *to-day*, as they here term it. In this case a hole is made like the shaft of a coal-pit, which is gradually enlarged as it is carried deeper, till the cavity assumes the shape of a bell. These are seldom sunk lower than eighteen or twenty yards; when at that depth fresh ground is broken, and new openings made, of similar depth and form. From this practice the land receives greater injury by working iron mines, than those of coal, and it is, therefore, not judged expedient to dig for iron ore, unless the beds are very rich. Then the thickness varies from two to twelve inches. The quantity of iron annually produced in this county amounts to between fifteen and sixteen thousand tons. See IRON.

The chief places at which calamine is obtained, are Calketon, Cromford, Bonsall, and Wirksworth. It occurs at various depths, but is generally found near a vein of lead ore: sometimes the two minerals are mixed, or run a considerable way by the side of each other; but more frequently, one ceases where the other begins, and a good vein of both is never found in the same place. The quantity prepared annually in this county is about 500 tons. In the crude state, its value is from three to four pounds a ton; but when refined, it is sold at nine or ten pounds. By the various processes it undergoes before it becomes saleable, it loses about eight parts in twenty. See CALAMINE.

Coal was obtained in Derbyshire so early as the reign of Edward II., both in the liberties of Norton and Alfreton. This is evinced by the grant made to the monks of Beauchief abbey by the lord of Alfreton, Thomas de Chaworth, who gave them licence to supply themselves with this substance in any quantity they thought proper, from either of the above places. It is found at different depths, and in some situations several beds are perforated by one shaft; but the upper ones are of inferior quality, and seldom worked. Here, as in Cumberland, the vein of coal is frequently separated, or broken, by some intervening substance, mostly clay; and the coal on one side is sometimes found lifted up or cast down ten or twenty yards from its level, on the other. Besides the home consumption of coal, which is very great, large quantities are annually sent to Sheffield; and by the different canals more is conveyed into Leicestershire, Nottinghamshire, Lincolnshire, and Northamptonshire.

Derbyshire also abounds with metallic ores, fossils, and various mineral substances; but it would exceed our limits to particularize all. Those who wish for such information are referred to Mawe's Mineralogy of Derbyshire, and the Beauties of England and Wales, vol. iii.

The mineral and medicinal waters of Derbyshire are, as might be expected in a country abounding with fossils, numerous. All those of a chalybeate and sulphureous nature arise in beds of shale, and probably derive their impregnation from this substance; the warm springs also are observed to appear near these beds, though they break out in the

stratum of lime-stone almost exclusively. The most celebrated warm springs are those at Matlock and Buxton; they occur likewise at Stony Middleton; and Middleton, near Wirksworth, had formerly a spring of this description, which was cut off some years since by driving a fough to remove the water from some lead mines in the vicinity. Those of Matlock and Buxton have obtained much celebrity for their medicinal properties, and are annually visited by a considerable afflux of company, who resort to them as well for pleasure as for health. The natural history of the Matlock and Buxton waters occupied much of the attention of the late Dr. Darwin, whose death has deprived society of one of its most valuable members, and science of one of her most distinguished sons. His principal observations on this subject were contained in a letter written to the Rev. Mr. Pilkington, and published in the "View of Derbyshire." Among the arguments which have been adduced respecting the origin of warm springs, the doctor favours the following: "That the water of these springs is raised in vapour by subterraneous fires deep in the earth, and that this vapour is condensed under the surface of the mountains in the vicinity of springs."

Amongst the sulphureous waters of Derbyshire, that which is highest in repute rises in the park of lord Scarsdale, at Kibbles-ton. In a glass it looks very clear and transparent; but in the well it appears of a blackish blue colour, tinged with purple, and any substance thrown into it assumes the same appearance. It is principally valued for its antiscorbutic qualities. When taken inwardly it acts as a diuretic, and has given relief to persons afflicted with the gravel. It has also been found efficacious, from external application, in various cutaneous diseases, but more especially in ulcerous complaints. The temperature of the spring is about forty-seven degrees. Several other sulphureous springs rise in different parts of the county, but have hitherto undergone very little examination.

The chalybeate waters are numerous, but the most celebrated spring of this nature is at Quarndon, about three miles from Derby. Persons of a weak and relaxed habit have been much benefited by its use: when taken in sufficient quantity, it generally operates as a cathartic; yet to produce this effect, exercise is sometimes necessary. Its temperature is nearly forty-nine and an half. Within 200 yards of the warm spring at Buxton, there is a chalybeate water of properties nearly similar to that at Quarndon. Other chalybeate waters are found at Morley, Chesterfield, Tibshelf, Duffield, and Bradley.

In the liberty of Heage, about midway between Crich and Belpar, is a martial vitriolic spring, the only one that has yet been found in this county. It is situated in a black boggy soil, and was accidentally discovered about thirty six years ago.

The principal rivers of this county are the Trent, the Derwent, the Dove, the Wye, the Errewash, and the Rother.

Derbyshire is situated in the diocese of Lichfield and Coventry, and sends four members to parliament, *viz.* two for the county, and two for the county-town. Pilkington's View of Derbyshire, 2 vols. 8vo. Mawe's Mineralogy of Derbyshire, 2 vols. 8vo. Beauties of England and Wales, vol. iii.

Design

DESIGN, in the *Weaving Manufactures*, signifies the pattern of any ornamented piece of cloth, when the ornaments are woven in the loom along with the fabric. A species of paper is used to lay down these ornaments to a scale, which is called design paper, and which serves to direct the weaver in his subsequent operations. In every species of ornamental weaving, the whole design is effected by the leaves of clasped twine, which move the various threads of that part of the yarn, which is stretched in the loom, and which is called the warp. These leaves are called heddles in Scotland, hralds in Lancashire, and may probably be known by other names in different parts of the country. The paper upon which the design is to be drawn, is ruled from top to bottom with a number of parallel lines, the intervals between which represent certain portions of warp. These, being again crossed by other parallel lines at right angles, the latter represent that part of the yarn which is inserted by the shuttle, and which is called the woof or weft. The design-paper, when ruled, has the appearance of a number of small squares, and in these the design is inserted with a black lead pencil, or with any kind of water colour, very frequently with vermilion, or red lake. Every interval upon the paper may be supposed to represent either one or more threads. When it will not occupy too much space, and when the design requires particular delicacy of shape, the most accurate way is to make every interval represent only one thread. At other times it frequently represents two, and sometimes more.

The five figures in *Plate IV., Miscellany*, represent the usual modes of drawing designs for the species of ornamented cloth most commonly made in Great Britain. Different ways of effecting ornaments in the loom are practised, according to the fabric of the cloth, and the purpose to which it is to be applied. In the lighter manufactures of the silk, lawn, and muslin trades, now chiefly used as ornamental parts of female dress, the fabric is generally so flimsy, that, when ornamented in the loom, the figures, in order to have any show, must be composed of yarn, much coarser than that which forms the ground or fabric of the cloth, and this yarn is sometimes dyed of different colours. Being most convenient in general, and the patterns more easily changed, the weft, or woof, is most frequently used for this purpose. *Figures 1 and 2*, are representations of this kind of work. In *fig. 1*, every square of the design-paper is supposed to represent one thread both of warp and woof. In *fig. 2*, it is supposed to represent two. For the application of these designs to the purposes of mounting looms, see the article DRAUGHT and *Cording*.

In the heavier branches of the manufacture of cloth, ornaments are effected without any alteration in the fineness of either warp or woof, and most frequently without any change of colour. The *figs. 3 and 5*, refer to these kinds of work, and the squares in each of these may be supposed to represent any number of threads from three to eight, according to the fineness of the cloth, and labour bestowed in ornamenting it. *Fig. 4*, is also a kind of ornamented cloth of the dimity kind of a stout fabric. Each square upon the design represents one thread. For the application of these, see the respective articles DIAPER, DIMITY, DOR-MOCK, and DRAW-LOOM, especially the last.

When designs are drawn upon paper, the distance of the lines is generally so much more than the diameters of the threads which they represent, that the figure upon the cloth will often be very different both in size and appearance from the design. To calculate this accurately is an important part of the business of a skilful manufacturer. The rules, therefore, for this, with references to the plate, will be found in the respective articles to which they refer.

Some general remarks upon the principle of designing ornaments upon cloth, and upon the analogy which subsists between the figure of any flower or pattern, when drawn upon plain paper, when reduced to the design-paper, and when woven into the cloth, may, however, be useful to those who possess an adequate knowledge of the art of manufacturing plain cloth, but who are not equally conversant with the various branches of ornamental weaving.

When an oblique or curvilinear figure is drawn or painted, either upon canvas, paper, or any other substance, no impediment exists to prevent the artist from drawing every oblique straight line at whatever angle of obliquity he chuses, nor from forming whatever curves will add to the beauty of the picture. But, when an imitation of this is to be transferred to design-paper, and from thence to cloth, the same facilities do not exist, and the utmost which the most skilful weaver can effect is only the nearest possible approximation to the original from which he copies. Every person at all acquainted with weaving knows, that the threads of warp are stretched in the loom, forming straight lines parallel to each other, and that these threads are intersected by the woof at right angles. No oblique pattern can, therefore, be formed in the loom, except by varying the point in the warp, where the intersection showing the pattern appears, and every change of this point must be at least equal to the diameter of one thread. Now, if we suppose that there are equal quantities of warp and woof in a web, and that a shift of one thread of warp is made, to the right or left, every time that a thread of woof is passed across, the diagonal line produced will form invariably an angle of 45° both with warp and woof. The diagonal here, then, is produced by the resolution of two equal forces, acting at right angles to each other. But an obliquity, confined invariably to an angle of 45° , would produce a very limited range of patterns indeed. *Figs. 1 and 2*, are specimens of such as may be effected by it. It becomes, therefore, necessary, in more extensive designs, to vary the obliquity of the angles frequently, and this can only be done in two ways.

1st. By shifting the point of intersection over more than one thread of warp, which will render the angle formed by the diagonal line and warp greater, and that by the diagonal and the woof less than 45° , or

2d. By inserting more than one thread of woof without shifting the point of intersection, the effect of which will be exactly the converse of the former.

It is to be observed, that by the diagonal line is only meant the apparent line which is presented to the eye; for as the shifts are at right angles, each will form either a square or parallelogram, the true diagonal of which is intended to be represented, and the means used are therefore only approximations to this.

When the design (*fig. 5.*) is examined, as all the squares forming the flower are black, whilst those which represent the ground are vacant, every shift, when minutely inspected, is evidently at right angles, although the general effect, when viewed at some distance, has the appearance of diagonal or curved lines. But, were this pattern woven upon a fine cloth, the diameters of the threads would be so much less than the measures of the squares which represent them upon the paper, that the angular corners which give the edges of the flower the appearance of being dented, would totally disappear, unless very minutely inspected, and the flower upon the cloth would be much smaller than that upon the paper.

The following table of the angles, formed between the diagonals of parallelograms, whose sides are in the same ratio to each other as those upon the design-paper, has been calculated to assist in reducing the drawing of designs, as nearly as possible, to correct imitations of the drawings or paintings from which they are taken.

TABLE shewing by inspection the angles of obliquity formed by colouring the squares of design paper for weaver, both by the warp and woof, from 1 to 9 squares each way; the line of woof being taken as the base.

Squares of Warp.	Squares of Woof.								
	1	2	3	4	5	6	7	8	9
1	45°	27°	18°	14°	11°	9°	8°	7°	6°
2	63	45	34	27	22	18	16	14	13
3	72	56	45	37	31	27	23	21	18
4	76	63	53	45	39	34	30	27	24
5	79	68	59	51	45	40	36	32	29
6	81	72	63	56	50	45	41	37	34
7	82	74	67	60	54	49	45	41	38
8	83	76	69	63	58	53	49	45	42
9	84	77	72	66	61	56	52	48	45

The angles may be continued down to 1° and up to 89°, as follows: By the warp the number of squares to be coloured for one square of woof will be for 85°, 11 squares; for 86°, 14 squares; for 87°, 19 squares; for 88°, 29 squares; and for 89°, 53 squares. And reversing the operation for the same numbers the angles will respectively be the complements of those quoted, *viz.* 11 squares 5°; 14 squares 4°; 19 squares 3°; 29 squares 2°; and 53 squares 1°.

To understand this table it is necessary to observe, that the left hand column from top to bottom contains the number of squares, coloured upon the design-paper, and forming the edge of the flower by the warp, or contained between one or more spaces from top to bottom of the paper. The cross columns at the top contain the same by the woof, or across the design, and the figures, where the one column crosses the other, give the angle which the diagonal of a parallelogram, whose sides are in the ratios of the two numbers to each other, would form with the base or cross lines. When the number of coloured squares each way is equal, the angle is always 45°, and in all others the angle formed by the cross squares is always the complement of the same number from top to bottom. The minutes have been thrown away, being unnecessary in practice, and the nearest degree,

whether a little more or less, taken.

When a pattern is to be reduced from a common drawing to a design for weaving, this table may be of considerable use; for if a cross line be drawn upon the original, the angles of obliquity may be taken with very considerable accuracy by a line of cords, or any of the usual mathematical processes, and a reference to the table will shew the number of squares which, when coloured, will produce the effect most nearly similar. Curve lines are formed merely by changing the angles of obliquity, as frequently as necessary. When it is desirable to make a smooth uniform line, it is always best to shift only one square at a time, and make the shifts more frequent; for when many are shifted, the square corners will be always too apparent; but where a rough edge is wanted, these may be resorted to.

The calculation of the size of the flower upon the cloth, compared with that upon the paper, is merely a case of simple proportion. In order to calculate correctly, the greatest number of squares coloured from right to left, and from top to bottom, must be counted, and the size of the flower each way measured; for design-paper is ruled to many different scales. The number of the reed, or, which is the same thing, the number of warp-threads in a given breadth, is then to be ascertained, and also how many threads are represented by each square. These points being fixed, the ratio of the one to the other will be readily found. A single example, taken from the damask flower, (*fig. 5.*) will illustrate this.

The squares coloured from right to left, counting from either extremity, are 107, and the measure is 5½ inches.

From top to bottom the squares are 113, and the measure 5¾ nearly.

Let it be supposed that this pattern is to be wrought upon what is called a five leaf damask, containing 2400 threads in the compass of 37 inches. Every square will then represent five threads either way; and the threads contained in the warp of one flower will be 535.

Then as 2400 : 37 :: 535 : 8.2479, or nearly 8¼ inches. The flower, therefore, upon this scale, will be 3½ inches broader upon the cloth than upon the paper, and the excess of length will be found by a similar proportion.

But were the same flower to be wrought as a spot, only two threads would be represented by each square, and the number of warp-threads would be 214 in each flower. Suppose then the muslin to be figured, to contain 3200 threads in 37 inches, the proportion would be

As 3200 : 37 :: 214 : 2.474, or nearly 2½ inches. In this case the same flower, on the cloth, would be less than one-half of its breadth on the paper. The great disproportion in the size of the two flowers depends partly upon the difference in the number of threads represented by one square, and partly by the fineness or set of the webs. In the first, the ratio of decrement is *directly* as 2 to 5; in the second, *inversely* as 12 to 16.

When looms are mounted to work fanciful patterns, if the range is not too extensive, heddles are used, which are moved by levers or heddles attached to them below by cords, and which are pressed down by the weaver's feet. When the range of pattern becomes too extensive to render this mounting convenient, another apparatus is adopted, which will be found in the articles DIAPER, MOUNTING, and the most extensive in that of DRAW-LOOM. The more common mountings belong to the article DRAUGHT and Cording.

Dipping

DIPPING, in *Calico-Printing*, a process used in dyeing blue, in which the cloth is immersed or dipped either in a solution of indigo, or of some substance capable of acting on indigo previously applied to the cloth.

The peculiar nature of indigo unfits it for the purposes of

dyeing by the ordinary operations of the art. It consists, as we shall have occasion to shew more fully hereafter, of a peculiar vegetable basis united to a portion of oxygen, to which it owes its colour and insolubility. When deprived of this oxygen, by substances whose affinity for it are greater, it becomes soluble in the alkalies and alkaline earths, and in

this state readily contracts an union with animal or vegetable stuffs. On this property of the alkalies to dissolve deoxygenated indigo, are founded two processes for dipping or dyeing blue, which form the subject of the present article. The first consists in immersing the cloth in an alkaline solution of indigo, and is employed in dyeing those goods, the ground of which is intended for blue or green. The parts meant to remain white, or which have already received some other colours, being covered with a reserve or paste, to protect them from the effect of the dye.

This process is very ancient.

The second is employed in dyeing those goods intended to exhibit a design or pattern in one or more shades of blue, upon a white ground, and is called "China blue," or generally upon the continent, English blue, the process having originated with the calico-printers of this country.

From time immemorial the nations of the east appear to have possessed a mode of dyeing silk handkerchiefs, and other articles of dress, by a rude but simple process, which is practised at this day, and has been adopted, and continues in use, in almost every part of Europe. It consists in tying knots with great address and nicety on the silk in such a manner, that when dyed, the parts enclosed within the knot remain untouched, displaying a ground of red, blue, or any other colour, variously, and oftentimes not in elegantly diversified with flowers of white or yellow, according to the primitive colour of the silk. This mode of dyeing handkerchiefs was introduced by the Saracens into Spain, where it is now practised to a very considerable extent. This, in all probability, was the first rude essay or attempt to imitate the printed linens of Egypt, and was succeeded by the mode now practised in India, of covering with a composition of wax and other ingredients, the parts intended to remain white. Hence we may date the origin of blue dipping, and though the process, as may be supposed, has been considerably improved since its introduction into Europe, yet the ancient practice is still in use; and wax printing is often employed with considerable advantage in the production of particular combinations of dark and light blue, which could not readily be obtained by any other process.

Of the Indigo Vat, and the Process of common blue Dipping.

The solution of indigo for blue dipping, is made in large oblong vessels of wood, stone, or other materials, to which the name of vats is given. Those which are made of wood require to be very accurately joined, and well secured with bolts and straps of iron; otherwise great loss may arise from the constant leakage, to which, without great precaution, they are subject. In general they are lined with lead, and though the expence in the first instance is four times that of wood, they are eventually much cheaper. They need fewer repairs, and afford absolute security against all loss by leakage, which, in a drug so costly as indigo, is a consideration of great importance. Stone vats have been tried in some places. At Rouen, according to Berthollet, they are constructed of a kind of flint-stone, well secured both outside and inside with a fine cement: and Pileur d'Appligny mentions some he had seen composed of large stone slabs screwed together at the corners, and the joints of which were covered with a kind of mastic varnish. Economy is the chief aim in all these various constructions, as it matters little what the vat is composed of, provided it will hold the dye; and those, in fact, are the cheapest, whatever they have cost, that suffer the least to escape.

The size of the vat varies considerably in different dye-houses, according to the nature and extent of the establishment, and the kind of work they are intended for. Four

feet wide, six feet long, and six or seven feet deep, are the dimensions of a well-proportioned vat, calculated for two pieces of calico, or 56 yards of cloth on a frame. Much smaller than the size here given are in use for frames of single pieces, and vats of still larger dimensions are employed by some, whose work and cloth require them one or two feet deeper.

The vats are all sunk in the earth, down to a level, or nearly so, with the floor of the dye-house. In some few old establishments, they stand two feet, or thereabouts, above the floor, as is universally the case on the continent. In this case, the frames are hoisted in and out by a pulley suspended over the vat, a most awkward and inconvenient practice, which is avoided by sinking them to the level of the floor. The frames are lifted out with ease by the hand, by two men or boys, one at each end, and in a range of six or eight vats, the frames are hoisted out and re-entered in half the time, and with half the trouble, required to manage the pulleys.

The number of vats necessary in a well arranged dye-house must depend greatly on the nature and size of the establishment. Eight of the size already given, ranged in one line side by side, form a good series: double or treble that number may be required, but with fewer, a dyer, whose quantity of work is limited, yet various, will find much inconvenience, especially when by long working the dregs or grounds have so accumulated as to require a repose of 24 hours at least, after raking up before the vats are fit for work again. It is on this account that deep vats are preferable to shallow ones; the mud subsides in them much sooner, and they require cleaning out and emptying less frequently.

The nature of the indigo vat is such, that the indigo is revived and precipitated from it whenever it comes in contact with the air. On this account, it is impossible to dye a piece evenly by winching or working it in the dye liquor, as in other colours. Those parts of the piece which had been most exposed, and on which, of course, most indigo had been precipitated, would exhibit deeper shades than those which had been less. The reserve, or paste, also, for white, when such had been applied, would be disturbed and washed off by the usual manipulations of dyeing.

On these accounts it is necessary to hook the pieces on a frame in such a manner, that when immersed in the vat, or taken out, the folds shall not touch each other. The frames are of wood, the length and width nearly of the vat, and of a depth sufficient for the width of the goods. The horizontal side-rails at the bottom are fixed, and form the base of the frame, and are furnished with small tenter hooks of copper an inch and a half, or two inches asunder, to which the edge or selvage of the piece is attached. The upper rails, which are also furnished with hooks, slide in a groove cut in the upright or corner posts, and may be adjusted to the width of any kind of cloth, and are retained in their place by a peg or pin. The piece is hooked in folds from side to side, and so evenly and tightly stretched, that when immersed in the vat every part is equally and alike exposed to the dye, and no one fold can touch another. The number of dips is regulated by the shade of blue required, and when finished, the goods are taken off the hooks and subjected to the ordinary operations of washing, rinsing, &c. &c. The solution of indigo, which, as well as the vessel that contains it, is generally called "blue vat" by the dyers, is made with lime and copperas, and in some cases with the addition of a small quantity of potash. In the due proportion of all the ingredients of this solution, and in the treatment of the vat, both during, and after working, consist the chief art of "blue dipping," in the management of which, however, there is less difficulty than in any other branch of blue dyeing.

whatever. The theory is so simple, and the practice, to those acquainted with the theory, so very obvious, that with common care and observation it is scarcely possible to err.

Indigo, as we have just before observed, is insoluble in the alkalies and alkaline earths, till deprived of its oxygen. Copperas is employed for this purpose in the vats we are speaking of, and orpiment in others, and in the pencil blue; both these substances having a stronger affinity for oxygen than the base of the indigo. On adding together, therefore, indigo, copperas, and lime, in suitable proportions, the lime in the first instance decomposes the copperas, and precipitates from it the oxyd of iron: this acts on the indigo, deoxygenates it, and renders it soluble in the lime, which, if in sufficient quantity, immediately dissolves it. The oxyd of iron, which has served to deprive the indigo of its oxygen, the sulphate of lime formed by the union of the lime with the acid of the copperas, and any lime in excess or more than necessary to effect the decomposition of the copperas, and the solution of the deoxygenated indigo, all precipitate to the bottom of the vat, and there remains in solution only lime and the base of indigo. There are few dyers and calico-printers who do not imagine that the solution of indigo consists of all the substances that have been used in its formation, and that the vat actually holds in solution indigo, copperas, and lime. They are not aware that solutions of these two latter substances are incompatible; they cannot exist together, one or other must predominate, as a very simple experiment will shew: Mix clear lime water, and copperas water together, and an instant precipitation will take place. As long as any copperas remains in solution, every successive addition of lime water will cause a fresh precipitate, which consists of oxyd of iron, and sulphate of lime, formed by the union of the lime with the acid of the copperas. None of the lime remains in solution. The precipitation ceases only when the whole of the copperas is decomposed, that is, when there is no longer any acid to form an insoluble salt with the lime. The solution will then be found to consist of lime water only. To those in the least acquainted with the principles of chemistry, these observations may appear minute and trifling, but to those ignorant of these simple facts (and the majority of those interested in the subject of the present article are ignorant of them,) the constitution of the blue vat must be wholly unknown, and its management, of course, exposed to all those chances of failure and derangement which must necessarily attend even long experience, when unaccompanied with clear and accurate ideas of the nature and properties of the different substances employed.

The proportions of indigo, copperas, and lime, necessary to form a blue vat, depend both on the quality of the indigo, and on the strength of the solution required. The quality of indigo varies greatly, some kinds, as the fine Spanish and East India, containing twice, and even thrice, as much colouring matter as the coarser kinds. In general from two to five pounds of good indigo to every hundred gallons of water, are sufficient to form vats for most purposes. They are sometimes, but rarely, required stronger; 40 pounds in a vat holding 800 gallons, will produce a solution of sufficient intensity to give a black nearly, at four or five immersions.

The finer the quality of the indigo, and the greater the proportion of copperas and lime, necessary to effect its solution. In general, however, one of indigo, two of copperas, and two of lime, are considered as the best proportions, and as such they are given by Berthollet, who, to profound chemical science, unites considerable practical knowledge,

and the best information concerning the processes of the dyers and calico-printers of France.

The indigo is previously ground in a mill with water, till it is reduced to a smooth paste of the consistence of cream. In its ordinary state of aggregation, it is scarcely, if at all, attacked by copperas and lime; all therefore that has escaped the action of the mill, and is put into the vat in a lump or imperfectly ground state, may be considered as totally lost. Every precaution therefore should be employed to guard against this, and when by rubbing it between the fingers, or on a pane of glass, it appears fine and smooth, and free from small hard, gritty particles, it may be removed from the mill, mixed up with four or five times its bulk of water, and poured through a fine sieve into the vat. Any lumps which may have escaped grinding are thus retained, and may be returned into the mill with fresh indigo.

The vat having received its charge of indigo, and been filled up with clean water, the copperas is next added. It is best and most speedily dissolved by suspending it in a wicker basket at the surface of the vat; it is sometimes thrown in, and will, in that case, when it is in large lumps, oftentimes lie undissolved at the bottom of the vat for weeks, in spite of frequent and even daily stirring. When the whole is dissolved, the lime is added, and the vat well raked up, till all its contents are intimately mixed, the lime dissolved, and the copperas decomposed. The action of oxyd of iron upon indigo requires time, and also repose; after the first raking, which should be continued during half an hour at least, it is best to suffer the vat to remain two or three hours undisturbed; the indigo and oxyd of iron fall down to the bottom, and are thus brought more within the sphere of chemical action, than when floating in the whole mass of water in the vat.

The choice of copperas is not a matter of indifference, as on its peculiar state depends its fitness or not for deoxygenating indigo. Sulphate of iron exists in two states dependent on the quantity of oxygen combined with its oxyd. At its minimum of oxydation, it forms a green solution, and when crystallized, a green salt, the green vitriol, or copperas of commerce; at its maximum, or second state of oxydation, it forms an orange-coloured, encrystallizable solution possessing very different properties from the former.

The green solution is distinguished by its great avidity for oxygen, and its disposition to pass to the orange, or fully oxygenated state. It is this affinity for oxygen that fits it for the solution of indigo. The copperas of commerce is however not unfrequently a mixture of the two salts or oxyds a portion of it either having acquired oxygen, whilst in a state of solution before crystallization, or more frequently perhaps by too great exposure to the air afterwards.

In this latter case its surface is covered with a reddish orange rust, and a portion of the salt is rendered useless for the blue vat having already acquired its maximum of oxygen. The chief difference in the quality of copperas, is however in the more or less perfect saturation of the acid, forming two distinct salts, which were known and distinguished by manufacturers long before chemists were acquainted with their existence. The first, and least esteemed, is a pale emerald green, and contains a great excess of acid; the other which is more fully saturated with iron, is a deep full green and is universally preferred, especially for indigo and Chinese blue vats. Some calico-printers imagine that the reddish coloured copperas is the best, or, as they say, the *strongest*, a prejudice which the manufacturer very easily accommodates by sprinkling a little fine sifted quick lime over the surface which soon covers it with a coat of orange rust.

The lime used for the indigo vat should be quick. Falles

time, when not too old, and too long exposed to the air, is the best. It should be well sifted, and freed from stones and lumps.

After two or three hours repose, the vat should be again well raked. It will now exhibit signs of incipient solution; instead of black, it will appear of a dark bottle green, and the surface will break into marbled veins of blue. These appearances will increase each time the vat is raked, which should be three or four times a day during two days. At each time the colour of the vat will brighten, and get paler, the marbled or veined appearance become more marked and strong, and when the solution is compleat, and ready for working, the colour, when raked up, will be a yellowish green. After a repose of ten or twelve hours, to allow the dregs time to subside, the vat is ready for work.

It is the practice of some dyers to add potash in equal quantity with indigo to the vat. The only advantage arising from this, is greater concentration of the solution than can be obtained by lime alone; but this is seldom required, and never, indeed, for the purposes of calico-printing; on the other hand, if potash be added to a vat containing little indigo, and calculated only for the paler shades of blue, the colour it will produce is less intense, than when lime alone is used, and the hue not at all improved.

It was formerly the practice to grind the indigo with a solution of caustic potash, and boil it in a strong lye, before adding lime and copperas, and pouring it into the vat. A great deal of trouble, and no advantage whatever attends this process, which is now universally discarded, except by those who regard all improvements as innovations.

Of the management of the vats both during work and after, we shall have occasion to speak whilst treating of particular kinds of work; which, after the preceding general view of the nature of the processes, and the mode of preparing the indigo vats, we shall now proceed to.

Of dark Blue ground, and white.

Dark blue grounds, with spots or figures of white, were amongst the first attempts at calico-printing in the East, and were produced, as we have before remarked, first, by tying knots on the part intended to remain white, and afterwards by covering them with a composition of wax. This process was subject to great inconveniences, arising from the unmanageable nature of the composition, which required keeping fluid by heat during the time it was applied, and could only be used in certain plain figures, such as round spots, ovals, &c. The designs were of course rude and similar, little variety being practicable where lines, stalks, leaves, or any object more figured than a spot or oval, could not be obtained.

At what time the paste or reserve now in general use was introduced, is not known; we are indebted for it to the continent, from whence, indeed, our first knowledge of calico-printing was derived. Though the formulæ for this paste differ much, every blue dyer almost, preparing it in a mode peculiar to himself, yet they are all essentially the same, a solution of copper of one kind or another being the principal ingredient.

If a solution of sulphate, acetate, nitrate, or indeed any soluble salt of copper, properly thickened for printing, be applied to cloth, and when dry, immersed in the blue vat, the part so covered will resist the action of the dye, and remain white. This does not arise from the mere mechanical resistance of the paste, which prevents the solution of indigo from entering the fibres of the cloth, but from the chemical action of the oxyd of copper, which imparting oxygen to the indigo, restores it to its former blue state, in which it

possesses neither solubility in lime, nor disposition to unite with the cloth. This effect of the oxyd of copper may be rendered very apparent, by pouring a solution of it into a solution of indigo, which is generally of a yellowish green, or when viewed by transmitted light, of the colour of small beer. The instant the two solutions are mixed, the indigo is revived, and precipitated in its original blue state, having acquired from the copper that principle of which it had been deprived by the solution of sulphate of iron. Every paste, or reserve, therefore, for dark blue grounds, must necessarily contain oxyd of copper; we give the following formulæ as most approved of any in use.

- I. To 1 gallon of water add,
4 lbs. of sulphate of copper,
12 lbs. of pipe clay.

Boil the whole up into a thick paste, strain through a cloth, and add to it half a pint of sulphuric acid, and five pints of thick gum water. Mix all well together, and strain again before printing.

- II. To 1 gallon of vinegar add,
1½ lbs. of verdigrease,
3 lbs. of sulphate of copper.

Dissolve them over the fire, and thicken with 12 lbs. of pipe clay, finely ground.

If the paste is not fine and smooth, run it through the mill, and add to it, whilst hot, 8 ozs. of linseed oil, and two quarts of thick gum water. Strain it carefully through a cloth before printing.

- III. To 1 gallon of water add,
2 lbs. of verdigrease,
3 lbs. of sulphate of copper,
3 lbs. of nitrous acid,
15 lbs. of pipe clay.

Boil them well in a copper pan, and, if necessary, grind them smooth, and add three quarts of thick gum water. Strain the whole very well before printing.

The first of these formulæ contains sulphate of copper only, the solubility of which is increased by the addition of a little sulphuric acid, which prevents the crystallization of the paste. The second, which is stronger, contains also acetate of copper, and the third, in addition to both these salts, contains a portion of nitrate of copper formed by the action of the nitrous acid on the verdigrease. This is a very powerful paste, and capable of resisting the vat a long time, and forming a white upon a ground nearly black.

The pipe clay used in thickening, is not merely useful in giving due consistence and body to the paste, so as to render it easily workable, but is very efficacious in resisting the dye; the same solution, thickened with gum only, will scarcely bear three immersions, but with the allowance of pipe clay here directed, will stand ten or twelve. No more gum, indeed, should be added than is just sufficient to break the adhesive nature of the pipe clay, and prevent it clogging up the print or block.

In working this paste the mull, or mallet, should be used very lightly, or not at all, if the pattern will admit of it. A gentle tap with the hand, so as to leave the paste wholly on the surface of the cloth, will produce the best work.

The cloth may be dipped an hour or two after printing, if required, but the whites are seldom so good as when kept three or four days. The paste gets hard and firm, part of the acid evaporates, and the solution of copper becomes more intimately incorporated with the cloth.

Dark blues, in general, require from five to ten dips, or immersions, according to the shade of blue required, or the strength of the vats employed.

If the vats are strong, five, or at most six dips, will give a

very dark blue, almost black, the intensity of which will be little increased by further dipping; the labour is greatly abridged by employing strong vats, but the whites are liable to great injury, as the solution of indigo, when concentrated, acts very powerfully on the paste. On this account the first vat should invariably be the weakest of the series, and never stronger than is sufficient to produce a full strong blue at seven, or even eight immersions. The second and third vats may be stronger, and so on to the last, which may be the strongest of all. Dark blues may be dipped and finished in the same vat, but it is more convenient to pass them in succession through a series disposed in a line in the manner we have before described.

When the piece is well hooked, and the frame ready, the vat must be well skimmed before the piece is entered. The surface of a blue vat is always covered with a film of revived indigo, more or less thick, according to the strength of the vat. This film it is necessary to remove before the frame is immersed, otherwise the revived indigo, which is no longer in solution, attaches itself, and adheres to the cloth in patches, producing unevenness in the dye, especially in the first vat. When skimmed, the surface of the vat is dark green, but the blue film re-appears in a few minutes; it should not be removed, therefore, till the frame is ready for immersion.

In five or six minutes the cloth has fully imbibed the dye, and little advantage is gained in general by keeping it longer in the vat. The frame is then lifted out, and placed slantwise in such a manner, that all the liquor which drains from the piece falls down into the vat again. When taken out, the cloth appears of a pale yellowish green, if the vat is weak, but if strong, more inclining to amber. This colour gradually changes, as the indigo, by absorbing oxygen from the atmosphere, becomes revived, and in five minutes the cloth appears uniformly blue; it is then ready for another immersion. Six minutes *in*, and six minutes *out*, is a good general rule for dipping dark blues, as the cloth will in that time have acquired the full effect of the vat, and *the green will also go off* in little more than five minutes, though the vat be very strong. The bottom edge of the piece retains the green hue the longest, because it is longest in draining from the liquor; care must be taken, therefore, never to immerse a piece till the bottom edge has been examined, and found perfectly ready for the dip. The consequence of entering a piece into the vat whilst the bottom edge is green, is, as might be supposed, that the edge will be the palest, the indigo not having been revived and precipitated upon it equally with the rest of the piece.

In dipping dark blues, the first dip is the most important; and if it fails, the work is inevitably ruined. First, if the vat be too strong, the whites will never be clear and sharp; secondly, if for want of due preparation the cloth does not uniformly receive the dye, the goods will scarcely ever be even when finished. Thirdly, if either from the paste being too strong, or the vat too weak, or not in proper order, the impression starts, or runs at the first immersion, the ground is sure to be freckled and uneven, and the whites bad.

Against the first source of error, the knowledge of the fact ought to be a sufficient guard; but if unavoidably it should happen that the leading vat is too strong, there is no other remedy than shortening the time of the dip, and keeping the frame in four or five minutes in lieu of six, till the vat becomes reduced in strength.

Imperfect bleaching, accidental impurity in the cloth, and long and partial exposure to heat and air, are amongst the causes which contribute most to prevent the cloth from receiving the blue dye.

It is the practice with many printers to give the cloth intended for this purpose an extra preparation, either by boiling in a lye of potash, or a solution of common salt. If the regular bleaching has been perfect, the first is wholly unnecessary, and the second absolutely useless.

Cloth that has been well bleached may, by long keeping, and partial exposure to the air, dust, and other accidental impurities, become so unfit for dipping, as to require some extra preparation. In this case the modes we have spoken of may be useful inasmuch as washing, soaking in hot water, squeezing, and the other attendant operations are useful, but clean, well bleached, and recently bleached cloth has no need of any such preparation.

If the paste be too strong, that is, if it contains too much sulphate, acetate, or nitrate of copper, it is liable to start or run in the first vat, especially when laid on in large bodies. This evil, if not too great, may be remedied by gently moving the frame up and down during the first two or three minutes after it is entered. It may also arise from the vat being too weak, and consequently containing too little lime in solution, and may sometimes be remedied by the addition of more lime. If in spite, however, of the motion of the frame, the addition of more lime, or of greater strength to the vat, the paste still continues to run, it is a sign the solution of copper is too strong, and the quantity must immediately be diminished.

When the green is gone off after the first dip, the frame is then moved on, and dipped in the second vat, taking care to skim it well before the piece is entered. In this way, after each immersion, the frame is moved on to the next succeeding vat, till it has received the number of dips required. This, as we have before observed, depends on the strength of the vat, and the shade of blue wanted; but as, during the process of dipping, the vats continually get weaker, the goods, after a certain time, will require an additional immersion, or even two or three, to get them up to the strength of the first pieces that were entered.

The strength of a blue vat is not exhausted in the same manner as the weld or madder bath, by the abstraction of the colouring matter from the solution, by the superior affinity of the mordant on the stuff. When a piece of cloth is immersed in the indigo vat, it becomes penetrated in five or six minutes completely with the dye, and will gain nothing, by being suffered to remain longer than is necessary for this purpose. When taken out, it carries with it no more indigo than is contained in that quantity of solution which it has imbibed, and carries out of the vat. But the instant the frame is lifted out, the liquor begins to drain from it back again into the vat, and pours down in small streams, thus exposing the solution completely to the atmospheric air. The indigo is in consequence revived and precipitated, so that the liquor which drains from the piece, and falls down into the vat, is for the purpose of dyeing, no better than so much water. Every frame that is entered thus effecting the precipitation of the colouring from matter two, three, or four gallons of the solution, the vat, especially the leading one, soon becomes reduced in strength. The second, third, and successive vats, are weakened in the same manner, and also by the exhausted liquor of the pieces, which at every dip after the first, is exchanged, as it were, for the fresh and strong solution of the vat it is immersed in.

When the goods have received the last dip, and have acquired their full shade of colour, they are taken off the books, and well winched in clean water; they are then, by the successive operations of washing and hot watering, repeated as occasion may require, freed from the paste, and rendered as clean as possible before going into the dours.

Souring is necessary to free them from the last remains of the paste, and give a brightness and finish to the whites. A solution of sulphuric acid, weak enough to be borne in the mouth without inconvenience, is sufficient to dissolve what oxyd of copper is left in the cloth after good cleaning. The goods are immersed in this ten or fifteen minutes, after which they are well washed and hot watered, and when dry are finished, or ready for any succeeding operations. The excellence of this kind of work depends on the clearness and purity of the white, and on the fulness and evenness of the blue. The directions we have given are, with ordinary care and observation, sufficient for the attainment of this.

When the vats have become exhausted by working, they must be *refreshed*. If a vat contains a tolerable charge of indigo, copperas, and lime, and has been worked only once, raking up alone will be sufficient to put it in a state for working again. When again exhausted, copperas and lime must be added to dissolve the revived indigo. The quantity must depend upon the size of the vat, and the supposed quantity of indigo which it contains. From 20 to 40 lbs. of copperas, and three-fourths of that quantity of quick lime, may be added at once to a vat of 1000 gallons, or thereabouts, and some idea may be formed of the effect which this should produce, by recollecting that one pound of indigo requires for solution about two pounds of sulphate of iron. It is proper always to have an excess of quick lime in the vat, but it is wholly unnecessary to make those frequent additions of lime without any thing else, which is the practice of many blue dyers. It serves no other purpose than to fill the vat speedily with dregs, which ought to be avoided as much as possible, as when they are accumulated to a certain pitch, it is necessary either to take them out, or suffer the vat to repose from 36 to 48 hours before it is fit for work after raking.

If equal quantities of copperas and lime have been used when the vat was formed at first, and three parts lime added for every four of copperas afterwards, any other addition of lime is wholly useless. Some idea may be formed of the state and condition of a vat, by observing its appearance when raked up. In general, if it looks dark green or black, it may be presumed it contains a quantity of revived or undissolved indigo, and copperas and lime are therefore necessary; this blackish appearance may nevertheless be occasioned by a very great excess of copperas, or sulphate of iron, the oxyd of which, when recently precipitated by lime, is dark green; as this, however, could arise only through great ignorance, or accident, it is not often likely to be the case, as the quantity of copperas required to produce this effect must be very great indeed.

When a vat rakes up yellow, or very pale yellowish green, it is supposed by some to contain too much copperas, and must be corrected by the addition of more lime. It is hardly correct, as we have before observed, to say a vat contains an excess of copperas, since this salt cannot exist in solution with lime. A vat may want lime, and in this case it will be very weak, of a pale yellowish green, produce a very feeble blue, and the paste will invariably *creep*, to use the dyers' phrase, or in other words, will run, and lose the sharpness and smartness of the impression, the moment it is entered in the vat. This may be the case at the time the vat contains a quantity of revived indigo also, and rakes up black, so that no certain conclusion can be drawn from the yellowish appearance aforesaid.

If a vat be weak, the froth which forms at the top during raking, is pale sky blue; the surface does not speedily break into marble veins, nor is it soon covered with a blue film. A strong well conditioned vat, on the contrary, when raked

up, becomes covered directly with a permanent and copious froth, the colour of which varies from a deep blue, when the vat is of ordinary strength, to a bright copper colour, which is always characteristic of a very strong solution, and the surface, when skimmed, is in an instant covered with a thick film of revived indigo. This film, and the deep blue and copper coloured froth, is the best and purest of the indigo, and is called the *flower of the indigo* by the old dyers. In skimming, great care must be taken that this is carefully preserved, and returned again into the vats at the time they are refreshed.

When a vat becomes so exhausted that further additions of lime and copperas have no effect in increasing the strength, fresh indigo must be added, with the proportions of lime and copperas before indicated.

If a vat remains several weeks unworked and without raking, it will absorb oxygen enough from the air to precipitate the indigo from the solution, so that, to the depth of 10 or 12 inches from the surface, it will consist of lime-water only, and must be well raked up before it is worked.

When the dregs have accumulated to much as to prevent the vat from clearing in 24, or at most 36 hours, and when the frame begins to touch the mud during work, it is time then to empty it out, taking care to dose the vat well with lime and copperas, so as to get out all the indigo before the dregs are thrown away as exhausted.

Of Pale Blue.

Pale blues are, in general, produced at a single dip; they require less indigo and labour than the preceding style of work, but more care and management to do them well. They are liable to be uneven and spotted in the ground, and the proper tone and shade of colour is a matter of great importance, and also of no small difficulty.

We shall speak first of pale blues and white, intended to be finished up with after-colours or not.—The paste for pale blue is precisely similar to that for the dark blue we have been treating of, except that it need not be so strong. Two pounds of sulphate of copper, dissolved in a gallon of water, and thickened with pipe-clay and gum, in the manner of the three pastes we have already given, will form a very good reserve for pale blue. Any other solution of copper will be equally efficacious, but the sulphate, as being the cheapest, may be considered as the best.

The preparation, or rather the condition of the cloth, is a matter of the greatest importance in pale blue dipping. If imperfectly bleached, or stained or impregnated with any earthy or metallic substance that will obstruct the entrance of the dye, the blue will infallibly be uneven. A difference in the quality of the cotton, in the fineness of the web, or in the hardness of the twist, of which the cloth is made, will occasion considerable variation in the shade of blue, and defeat every attempt, on the part of the workman, to do justice to his work. To guard as much as possible against this, the cloth, in the first place, should be selected purposely, rejecting all those pieces which shew unevenness in weaving, or variation in the quality of the materials.

The goods should be in the best possible state for printing; fresh from the bleach ground, carefully kept from dust or dirt of any kind, and sufficiently damp to make them take a stiff calendering. As soon after printing as convenient, they should be removed from the warm shop to a cool situation, where they will not get parched and dry, and dipped at furthest the following day.

All these precautions, however, are inadequate to secure an even and level ground, without recourse to the improved

method of dipping, for which we are indebted to the calico-printers of London.

This improvement, whether considered with reference to the particular style of work, of which we are now treating, or its application to other branches of blue dyeing, the most important that has lately been introduced, consists in dipping the goods in clear lime-water before they are entered in the blue vat.

If the piece becomes uniformly wet throughout, and shews no streaks or patches of white, it may safely be transferred to the blue vat as a piece that will take an even dye. If, however, after remaining five or six minutes in the lime-vat, there are parts which are not completely wet, it must be dipped five or six minutes longer, and again taken out and examined. All those pieces which, after two, or, at most, three immersions, still refuse admission to the lime-water, are rejected as unfit for dipping, and the paste being removed by souring, are appropriated to some other course of work to which they are better adapted.

The vat for pale blues is, in general, the same as for the dark grounds, care being taken to select one that will give the shade of blue required. It is usual to employ the old and nearly exhausted vats for this purpose, but the blue is never so bright and lively as when fresh indigo, and that of the finest quality, is employed.

The hue is greatly improved by souring, a necessary operation, to free the goods from the paste, and still further, by winching them in a solution of white soap 10 or 15 minutes, at a heat of 120°.

Mr. Hausman observes, that if the goods are plunged in a weak solution of sulphuric acid immediately on coming out of the vat, the blue is more lively and full than when previously rinsed and washed.

Mr. Chaptal employs for pale blue grounds without white, and for green grounds also, a vat composed of indigo, potash, lime, and orpiment. This solution, which is the same precisely as the pencil-blue of the calico-printers, affords a much more delicate colour than that with lime and copperas, the cause of which is not clearly understood, though it most probably arises from the different degrees of deoxydation produced by the two substances.

This vat is formed by boiling 10 lbs. of fine Spanish indigo, 10 lbs. of potash, 20 lbs. of quick-lime, and 5 lbs. of orange orpiment, in about 30 gallons of water, and pouring it, when the solution is complete, into the vat containing about 800 gallons of water, and 20 or 30 lbs. of lime. When worked, it must be raked up well the instant before the frame is entered, and when exhausted, refreshed with additions of the same solution.

If a piece of cloth, printed with the reserve or paste before described, be dipped in this vat, the copper becomes precipitated and fixed by the sulphuretted hydrogen which it contains, and produces a brown stain instead of a white. It is possible, however, with extraordinary care and management, to succeed in obtaining good whites in this vat, and the following process may be employed with success, though it is still capable of further improvement.

Prepare a paste by dissolving 2 lbs. of sulphate of copper in one gallon of acetate of alumine, or the common aluminous mordant of the calico-printers, add to it 1 lb. of nitrous acid, and 8 lbs. of pipe-clay; boil well and strain it through a fine cloth, and when cold, add as much thick gum-water as is barely necessary to give it the due degree of consistence for working. In printing this paste the mallet should never be used, a gentle tap with the hand, if the block is true and in good order, will leave the paste, as it should be, wholly on the surface of the cloth. Dip six or

eight minutes in the lime-vat, and when taken out, suffer the piece to drain two or three minutes before entering in the blue vat. The vat should be strong enough to produce the shade required in two minutes, after which the frame should be withdrawn and plunged instantly in a vat of clear water, and moved and agitated therein till the green goes off. When washed and soured, if the work has succeeded, the white will be clear and prominent, and the blue the finest that can be produced on cloth. It is remarkable, that a strong vat produces better whites than a weak one, on this account care must be taken, that the solution be of a proper strength. The utmost nicety is required in preserving the cloth for this vat from dust or dirt of any kind. Goods that have been long bleached, and not carefully secluded from the air, are wholly unfit. They ought, in fact, to be taken fresh from the sours, for every, even the smallest particle of metallic substance that is in the cloth, when dipped in this vat, will produce a brown stain, and if the cloth is uniformly tainted with it, entirely ruin the blue.

In dipping pale blue grounds, it is sometimes necessary to protect colours that have been previously applied, from the effect of the blue, as red or yellow flowers for example, which would otherwise become purple and green. The solutions of copper cannot be employed for this purpose, as they injure the colours, especially madder reds, or purples, very much, and are not wholly removed without souring, an operation which goods of this description cannot be subjected to.

The reserve most commonly used, is simply a paste of pipe-clay or Spanish white, boiled to a proper consistence, and mixed with an equal quantity of thick gum-water. This does not affect the colours upon which it is applied, and is easily removed by hot water and washing; but as it opposes merely a mechanical resistance to the dye, and fails the moment it becomes softened, it will not bear a dip of more than one minute or two. This is an inconvenience of great magnitude, when the pale blue ground is much exposed, and not covered with any kind of design calculated to hide unevenness in the dye. The following paste is recommended and used, by some, as capable of resisting much longer than the former:—

One pound of finely ground pipe clay,
Four ounces of gum-arabic,
Two ounces of suet,
Two ounces of wax, and
One ounce of resin.

Boil all these ingredients together, in as much water as will form a paste of sufficient consistence not to run. This paste can only be applied with the pencil, and in large masses. It is removed with great ease by hot water and washing, without any injury to the reds, or other colours it has covered.

The solutions of lead possess the property, though in a much smaller degree than copper, of resisting the indigo vat, and may be used with advantage for pasting reds and other colours, which are but little injured by them. We have seen the following paste used with great success:—

Dissolve two pounds of acetate of lead in a gallon of water, add two ounces of tallow, two of wax, and two of resin, and as much pipe-clay and gum as will make it of a proper thickness for printing or pencilling. This paste will resist a dip of three or four minutes; it must, however, be laid on in good bodies, and succeeds better with the pencil than block.

In pale blue grounds, with black and white figures, &c. it is often necessary to print both the black and the paste

at the same time, to save the expence and trouble of after-grounding. The black for this purpose is generally chemical black, for an account of which we must refer to the article *COLOUR-making*. The sulphate of copper paste is generally used, but as the goods cannot, on account of the black, be passed through the sours to free them from the oxyd of copper, which imparts a greenish hue to the white, it is better to employ the nitrate of copper, which is cleared by hot watering and washing much more completely.

If the patterns contain very large masses or bodies of black, the acetate of iron, or what the printers call black colour, must be used, increasing the strength to double that required for an ordinary black; so that when the goods are dipped, and as well cleaned as possible, by repeated washing, &c. they may be passed through water rendered slightly acidulous with nitrous, or what is still better, acetic acid, without materially impairing the strength of the mordant.

The white is completely freed from the oxyd of copper by this slight souring, and takes no stain in the dye copper, when the black is raised with sumac and logwood.

It is proper to observe, that the goods, before souring, should be completely freed from all superfluous paste, either of the black or white; and the iron, by repeated hot watering, at a temperature of 140°, oxygenated as highly as possible. In this state it is scarcely soluble, either in nitrous or acetic acids, and will bear weak solutions of them 15 or 20 minutes.

Of Refsling Mordants.

When a pale blue is intended to exhibit other colours on the ground, as red, pink, yellow, orange, &c. the paste or reserve is often mixed with a mordant capable of producing these colours in the dye copper.

The common paste alone will produce a yellow with weld, quercitron bark, fustic, &c. if the piece be simply rinsed and washed before dyeing.

In this case the oxyd of copper which remains in the cloth attracts the colouring matter, and though it is greatly inferior as a mordant, to the acetate of alumine, yet, with care and management, it is capable of producing, with weld, a pale and beautiful yellow. The only difficulty consists in getting the colour even, and this is best attained by employing those solutions of copper which are most soluble, and using them somewhat stronger than is merely necessary to resist the vat.

When dipped, the goods should be well rinsed in the river 15 or 20 minutes, and afterwards rinsed off in a copper of warm water, with a shovel full of cow-dung. Too much dung, or too great heat, will injure the yellow, the temperature should not exceed 100°, and after winching again in the river, they should be dyed at a heat considerably below this, if weld is used, and not exceeding 75 or 80 if dyed with bark.

Oxyd of copper, when dyed at a high temperature, invariably becomes dull, especially when bark or sumac are employed. With weld there is less risk of injuring the brightness of the yellow, but long continued heat impairs it greatly.

This mordant does not at all answer for reds; with madder it affords a dull wine-coloured dye, and with brazil, peachwood, and cochineal, dull, heavy colours, more inclining to pompadour or chocolate than red. When mixed, even in small proportions, with the common aluminous mordant, its effects are very visible, when dyed with any of the above-mentioned drugs.

It is nevertheless employed for deep full reds, upon pale

blue ground, according to the following formula, which is excellent for a yellow or orange:—

Dissolve 2 lbs. of acetate of lead, and 2½ lbs. of alum, in a gallon of water; pour off the solution from the precipitate, and add 8 ozs. of sulphate of copper; thicken with 1½ lb. of starch, and 4 lbs. of fine pipe-clay. When cool, strain the paste through a cloth or sieve, and give the goods six days age before dipping. Dip three minutes in a well-conditioned vat, and transfer the frame from thence instantly to the water-vat.—Rinse off, and prepare for dyeing in the same manner as before directed.

The following formula is in use for resisting reds or yellows:—Dissolve in one gallon of warm water 3½ lbs. of acetate of lead, and 5 lbs. of alum; thicken it (with the precipitate in) with the best Senegal gum, and add 2 ozs. of white arsenic, ground as fine as flour; 4 ozs. of common salt, and 4 ozs. of corrosive sublimate. Give the goods two or three days age before dipping, and keep them from three to five minutes in a good vat, or less, if you can get the shade of blue required. Plunge them in the water-vat the instant they are taken up, and rinse and finish as before.

Bark or weld drabs and olives, as they do not so soon shew any slight tinge of blue which may have penetrated the paste, may be simply thickened with good starch, and from 12 to 16 ozs. of suet per gallon, to enable them the better to resist the vat. If this should not suffice, from 2 to 4 ozs. of sulphate of copper may be added, but it must be observed, that this will change the hue of the drab, and make it more an olive. A little pipe-clay, not more than 2 lbs. per gallon, may be employed also with advantage. It is very efficacious in keeping out the dye, and, in so small a quantity, will not materially affect the fullness and evenness of the mordant.

Solutions of tin, more especially the nitro-muriatic, are employed by some calico-printers, in conjunction with the aluminous mordant, for resisting reds and yellows. They are not very powerful in keeping out the blue, and, with madder, afford but feeble colours: the yellow they produce is bright, but pale.

In general, those solutions which are most efficacious in resisting the vat, are the worst mordants, as those of copper for example; but as they will bear a long dip, and the evenness of the blue is thereby ensured, this advantage, in one colour, is considered as sufficient compensation for want of brilliancy in the other. The common aluminous mordant, thickened with gum and a little pipe-clay, or with starch and pipe-clay, forms infinitely the best mordant, and will resist the vat a few seconds, but not sufficiently long to make the work secure. The recent improvement in this kind of dipping, however, by the use of warm vats, has removed a great many difficulties, and enabled some calico-printers to produce work of very superior merit.

The great and the only advantage attending warm vats, is the celerity with which the dye penetrates the cloth; so that all the effect of a six minutes' dip in a cold vat, may, in a warm one, be obtained in the same number of seconds. The frame, in fact, is plunged in only for a moment, and instantly taken up; and, in this short space, the vat, however strong, has not time to penetrate the paste or mordant.

The vats may be variously heated, as best suits the nature of the establishment. Steam affords the most easy and efficacious means, and may either be thrown into the vat through a pipe and valves, in which case the steam itself is condensed in, and mingles with the solution of indigo, or the vat may be, in part surrounded with a casing, into which the steam may be admitted, and give out its heat, without filling the vat with condensed water.

The first is the simplest and most economical mode; but it requires certain precautions which the other does not. In the first place, before the steam is admitted into it, the boiler should be *blown*, that is, completely emptied of air; for if it passes along with the steam into a vat, the indigo will be revived, and precipitated from the solution, and the vat rendered unfit for dipping. In the second place, if the vat, when cold, is only of the proper strength, the admission of so much steam, and consequently of condensed water, as will be necessary to raise it to the temperature required, will weaken it considerably; and lastly, some inconvenience may arise from this great accumulation of condensed water, unless due allowance be made before it is admitted, and care be taken never to turn it in when the vat is full.

The second mode is subject to none of these inconveniences. The vat can neither be weakened by air from the boiler, nor by condensed water, since the heat is transmitted wholly through the casing. The expence, however, is very considerable; still it is greatly preferable to the plan which some printers have adopted, of constructing cast iron vats, and heating them by furnaces built underneath.

The temperature at which they can be employed, varies according to the kind of work, and the power which the paste possesses of resisting a hot vat.

From 60 to 80° will be sufficient for most purposes, and a vat of tolerable strength will, at the latter temperature, produce a good blue in ten or fifteen seconds.

Of coloured Paste.

By mixing both colouring matter and mordant with the reserve, we obtain pastes which at the same time communicate colour to the cloth, and resist the blue; not only saving the necessity of dyeing, but enabling us to form combinations of colours, incompatible by any other process. This branch of blue dipping is still in its infancy, and little has yet been done towards its perfection. We shall therefore have little else to do in treating of this part of our subject, but to state the few facts on which it is founded, and suggest some hints for its future improvement.

If a solution of sulphate or acetate of iron be mixed with the reserve or paste for white, it will, when dipped and rinsed off, leave a buff or orange stain, not very strong, indeed, nor always very even; but applicable and useful in some cases. This paste has been long known and employed.

If instead of acetate of iron a strong decoction of bark, or French or Turkey berries, be mixed with the reserve, a yellow will be obtained, full, but less bright, than when raised in the weld copper.

Thus by combining different colouring matters with the mordants proper for fixing them on cloth, and also with substances which have the property of resisting the blue dye, various coloured pastes will be obtained.

The solutions of tin, from their forming combinations with most colouring substances which are but little affected by acids, seem likely to be of considerable use in the composition of pastes of this description. The muriate of tin destroys the resisting power of solutions of copper by de-oxygenating them; but the nitro-muriate, or highly oxygenated solutions, produce rather a contrary effect; they are these which should therefore be tried.

Of China Blue.

The process for China blue dipping consists in applying finely ground indigo, in its crude and undissolved state, upon the cloth, and fixing it by alternate immersions in solutions of sulphate of iron and lime.

The same thing takes place upon the cloth, that is effected

in the ordinary blue vat when indigo is dissolved; in both cases the indigo is de-oxygenated, and prepared for solution by the copperas, and afterwards dissolved by the lime.

The different shades of colour in China blue dipping are produced by reducing, more or less, the standard colour, which is prepared in the following manner.

1st. Grind in a metal pot with balls, or by any other contrivance, 10 lbs. of good indigo, 8 lbs. of good copperas, and 5 lbs. of orpiment, with 2 gallons of water; when the whole is nearly ground, add two quarts of very thick solution of gum senegal, and grind a few hours longer.

2d. Prepare a solution of sulphate of iron by dissolving 2 lbs. in a gallon of water, adding a quarter of an ounce of pot-ashes, and suffering the precipitate, if there is any, to subside. Reduce the ground blue (No. 1) with as much of this clear solution (No. 2) as will bring it to a proper consistence for working, and print with this for the dark full blue. When dipped, this colour will have nearly the effect of black, especially in small bodies.

For pale blue, reduce the standard with 10, 15, or 20 measures of the solution of copperas, and an equal quantity of acetate of iron, or common iron liquor thickened with gum. With 50, 60, or even 90 measures of sulphate and acetate of iron, one measure of the standard blue will give very good shades of pale blue. When the pattern, whether black or plate, will not work in gum, a portion of the acetate of iron must be thickened with starch, or flour, and ground up in the mill with its due proportion of the standard. When worked on plates, wooden doctors, especially lime tree, are preferred to steel ones; they clean the plate much better, and give a fine neat impression.

The vats are of the same form, and generally of the same dimensions, as those before described; they are, however, never lined with lead; wood, or stone, being considered sufficiently secure for solutions of little value, compared with those of indigo. They are disposed in a line, a copperas vat, and a lime vat alternately; or when the mode of dipping allows it, a lime vat between two copperas vats, forming a system in which two frames are worked; the lime vat being thus kept constantly employed, the copperas vats only alternately. The copperas vats are made up of different strengths, according to the work intended to be done; strong thick goods, such as Marseilles quilting, &c. require stronger vats than canoes and muslins. The first require the solution to be of sp. gravity 1040, the latter about 1030. These are the most economical points, but good work may be done at any point between 1025 and 1050. Lower than 1025, the colour will be pale and faint, though even; and higher than 1050, it is liable to be uneven, some parts being very deep and full, and others mealy and spoiled.

The lime vats are set with fine sifted quick lime, recently slaked, in the proportion of 150 lbs. to 1000 gallons of water.

When the pieces are hooked, and properly arranged on the frame, they are entered first into the lime, and the dipping proceeds as follows.

1. Entry in the lime vat 5 minutes.
2. in copperas vat 30
3. in lime vat 10
4. in copperas vat 30
5. in lime vat 20
6. in copperas vat 45
7. in lime vat 45

During the first five minutes in the lime, the frame must be gently rocked, or moved up and down, then drawn up and tightened. The vat, both now, and at every subsequent dip, is well raked up before the frame is entered. When entered

in the copperas vat, rock five or six times, to detach the loose lime from the piece.

At the second entry in the lime, rock the whole time.

At the second, and every succeeding entry in the copperas vat, rock five or six times as before, to detach the lime.

At the third and fourth entry in the lime, rock five or six minutes, and now and then.

The reason for finishing out of the lime, is to keep the frames and hooks free from the rust and incrustation of the copperas, which it loosens, and renders more easy to detach and clean; with respect to raising the colour, it makes no difference whatever.

When the piece comes from the copperas vat the second time into the lime, it will appear a grass green colour, if there be a proper quantity of lime in the vat. If too little, the piece will appear yellowish, and more lime must be added.

Take off the pieces quickly after the last dip, and winch them briskly in the water-pit a minute or two at the most. Get them into the fours, and after winching over twice or thrice, let them lie an hour or two, after which winch again four or five times, and wash well in the wheel. Hot water them, and wheel again before hot souring, which is done in a four of spec. gravity 1015, heated to 180°. Winch the goods four or five minutes in this, after which wash, hot water, &c. and finish for drying.

If the goods are kept too long out of the cold sour after the last dip, the oxyd of iron, with which they are coated, oxygenates very rapidly, and the cloth becomes buff or orange. It is with difficulty that the iron is disengaged, and not without long and very strong hot souring.

The cold sours soon become foul with the loose superfluuous indigo, which is detached, and unfits them for light goods, long before the acid is saturated.

In this case it is economical to add two or three shovels full of fine well-beaten clay, previously mixed up with water; when this is well incorporated with the sours, and suffered to subside, it carries down with it great part of the floating indigo, and renders them fit for use again.

After every day's work the lime and copperas vats must be refreshed.

From 25 to 35 lbs. of sifted lime, according to the size of the vat, and the number of pieces that have been passed through it, must be added every night.

No harm can arise from excess of lime, excepting the unnecessary expence of more than is required, and the accumulation of sediment or mud in the vat which will soon require removing.

Ten pounds of copperas are generally added for every piece of calico that is dipped. This is suspended at the surface in a wicker basket, and suffered to remain till all is dissolved. It is quite unnecessary to rake up the vat, as the fresh additions of copperas will incorporate uniformly without stirring, which, by muddying the vat, may do mischief. Care must be taken to use the hydrometer frequently to correct any deficiency or excess which may arise in the sp. gr. of the solution of sulphate of iron.

In making new or fresh copperas vats, after having brought them to the standard on the hydrometer, add to every 1000 gallons four or five gallons of the lime vat (raked up) and one pound of potash. This is to neutralize the superabundant acid of the copperas.

The grass green Yorkshire copperas is the best for this purpose, it contains the least free acid; the pale whitish green is the worst, and when such is used it will be proper occasionally to throw into the vat about one pound of potash, and four or five gallons of muddy lime water.

When daily worked the lime vats should be emptied out, and wholly renewed once a month at least.

The copperas vats are never wholly emptied, but when the mud accumulates so as to be troublesome and endanger the safety of the work by resting on the lower edge of the piece, it must be taken out with a scoop or shovel proper for the purpose.

The ground of those goods which shew much white will in general be sufficiently clear when finished according to the preceding directions, the white is however greatly improved by a gentle soaping, and one or two days exposure on the grass.

In general, better work may be produced in the winter months than in summer: in hot weather, the colour is liable to be uneven, patched and mealy, the cause of this has not been well ascertained, though, in all probability, it arises from the increased action of the sulphate of iron and lime at an increased temperature: it is not unlikely that weaker copperas vats would be found to act better in summer than strong ones, as the effect of temperature would thereby in some degree be counteracted.

From the nature of the process of China blue dipping, it must be evident that it must precede any other application of colours to which the cloth is intended to be subjected. If, for instance, reds or yellows are to be introduced, these must follow the operation of dipping; as they would inevitably be ruined by repeated immersion in copperas and lime, or wholly discharged by cold and hot souring.

DIPPING, in *Magnetics*, is a certain degree of inclination, which a magnet or magnetic body, be it natural or artificial, endeavours to attain in most parts of the world. Amongst the properties of a magnet, this of its dipping undoubtedly is one of the most admirable; but with a magnet already possessed of its characteristic properties, this dipping is not easily discerned; it being difficult to say, whether the inclination of one of its extremities below the horizontal plane, and of course the elevation of its opposite extremity above that plane, is owing to the magnetic virtue, or to the want of mechanical balance, (*viz.* to its being heavier on one side of the fulcrum than on the other,) and it was evidently on this account that the dipping of the magnet was not discovered so soon as its property of directing itself north and south, or nearly so. See *MAGNETISM*.

The easiest method of observing this magnetical property is as follows. Suspend an oblong and *unmagnetic* piece of steel either upon a vertical pointed wire, after the manner of a common compass-needle, or by fastening a fine thread to its middle; so that the oblong piece of steel may remain perfectly balanced, and of course horizontal. (A common oblong sewing-needle, having a thread fastened to its middle, will answer sufficiently well.) Then let this piece of steel or needle be rendered magnetic by the mere application of two powerful magnetic bars to its extremities; taking particular care not to disturb its point of suspension; and when this has been done, and the magnets have been removed, the piece of steel or needle will no longer remain in an horizontal situation, but one of its extremities will dip; that is, will incline itself below the horizontal plane, and its opposite extremity will raise itself above that plane, making an angle with it which is different in different parts of the world, and in some places it vanishes; that is, the needle will remain horizontal. This angle is also various in the same fixed place at different times; this latter variation however is but trifling. In England, the north end of the magnet tends downwards. A clearer idea of the different inclinations of the magnet, or magnetized steel, in different parts of the world, as well as

of the cause upon which that phenomenon depends, may be derived from the following experiment. Take a globular magnet, N S, *Plate IV. Magnetism* fig. 22, commonly called a *terrella*, or a magnetic steel bar, N S, fig. 23. (For by drawing a circle round the latter, one may easily figure to himself the form of a globular magnet.) The extremity N of this *terrella*, or steel bar, is its north pole, and the extremity S its south pole; and A is its middle, or equator. Place it upon a table as CD; then take another small and oblong magnet, or a common sewing-needle rendered magnetic; suspend it by fastening a fine thread to its middle, in such a manner as to remain in an horizontal position when not influenced by any other magnet. Now, if the said small magnet, being held by the upper part of the thread, be brought just over the middle of the large magnet, within two or three inches of it; you will find that it will turn itself so as to direct its south pole *s* towards the north pole N of the large magnet, and its north pole *n* towards the south pole S of the large one; it being a well-known law in magnetism, that poles of different denominations attract each other. It will be further observed, that the small magnet, whilst kept just over the middle A of the large magnet, will remain parallel to it or to its magnetic axis; for in that case the poles of the small magnet are equally attracted by the contrary poles of the large magnet, which are equidistant from the former. But if the small magnet be moved a little nearer to one end than to the other of the large magnet, then one of the poles of the former, namely, that which is nearest to the contrary pole of the latter, will incline itself towards it; and of course the other extremity will be elevated above the horizon. This inclination of the small magnet will be found to increase in proportion as it is brought nearer and nearer to one of the poles N or S; and, at last, if it be brought directly opposite to one of those poles, it will turn its contrary pole towards it, and will place itself in the same straight line with the axis of the large magnet, as is indicated by the figures 22 and 23, wherein the like parts are denoted by the same letters.

It must now be observed, that all the facts that have hitherto been noticed relative to the subject of magnetism, tend to prove, that the whole earth is, or must be considered as a large magnet; having its magnetic poles, magnetic equator, &c.: hence a magnetic needle, or any other magnet whatever, situated on different parts of the earth's surface, inclines, or tends to incline, the one or the other of its extremities, towards the horizon, or towards the axis of the earth, in the same manner and for the same reasons that compelled the small magnet *ns* of the preceding experiment to assume its various directions when placed in the vicinity of the large magnet N S. For, admitting that the north pole of the earth is possessed of a south magnetic polarity, and that the opposite pole is possessed of a north magnetic polarity, it follows, as is confirmed by actual experience, that when a magnet, properly shaped and properly suspended, is kept near the equator of the earth, it must remain in an horizontal situation; that if it be moved nearer to one of the poles of the earth, it must incline one of its extremities; namely, that which is possessed of the contrary magnetic polarity; that the said inclination must increase in proportion as the magnet, or magnetic needle, recedes from the equator of the earth; and, lastly, that when brought just over either of the magnetic poles of the earth, it must stand perpendicular to the ground; viz. in the same straight line with the axis of the earth.

The reader must not be surprised to hear that a south magnetism is attributed to the north pole of the earth; it being only meant, that it has a magnetic polarity contrary to that end of the magnetic needle which is directed towards it; and as we call the same end of the needle a north magnetic

pole, we must of necessity attribute a contrary power, that is, a south magnetic polarity, to the northern part of the earth.—With a proper change of names, the same remark must be applied to the southern part of the earth; viz. it must be considered as being possessed of a north magnetic polarity.

By a little attentive consideration it will be easily comprehended, that the true and natural situation of a magnet, or magnetic needle, is a combination of its horizontal and vertical direction; viz. the magnetic needle endeavours to place itself in the plane of the magnetic meridian, and in a direction more or less inclined to the horizon, according as it happens to be situated, nearer to or farther from any of the magnetic poles of the earth. And this natural direction of the magnet is called the *magnetical line*. Therefore, in order to observe the true dipping of the magnet, the magnetic needle, or oblong magnet, must be placed in the magnetic meridian; viz. in the usual direction of the compass at the place of observation; otherwise the inclination of the magnet will be greater than it ought to be, as may be easily derived from a due consideration of the combined forces which act upon it. Hitherto we have considered the earth as an uniform and regular magnet, having the magnetic poles in its real poles, and its magnetic equator in its true or astronomical equator. And if such were the case, the dipping angle, which the magnetic needle makes with the horizon, would bear a certain determined ratio to the latitude of the place; so that by observing that angle, the latitude of the place might be deduced from it, without the need of any astronomical observation, which would prove of the utmost advantage to navigators; the case, however, is far different, as will be more particularly noticed in the sequel. For the present it will be worth while to mention, that after the discovery of the dipping property of the magnet, sanguine expectations were entertained respecting the advantages which might be derived from it, and it was imagined, that not only the latitude, but the longitude also of the place of observation, might be indicated by the dipping angle of the magnetic needle; for though it soon appeared, that neither the magnetic poles, nor the magnetic equator, of the earth, coincided with its true poles and true equator; yet that very same circumstance seemed to furnish the method of determining the longitude; which method was grounded upon the following principle; viz. that if the magnetic poles, though different from the real poles of the earth, be either fixed in other places, or do move with any regularity, it follows that the magnetic equator must likewise differ from the real equator; and must cut it at a certain angle; therefore, in the same parallel of latitude, but in different longitudes, the dipping angle of the magnet must be different; hence, by observing the dipping angle of the magnet at any particular place, the longitude of the place would thereby be indicated. Impressed with this idea, during a long period, subsequent to the discovery of the dipping of the magnet, the scientific world made various and strenuous exertions for the purpose of rendering that magnetic property subservient to navigation. Innumerable calculations were made, and various instruments were contrived. Mr. Henry Bond, a distinguished teacher of the art of navigation in London, calculated a table of latitudes corresponding to every five minutes of the inclination of the magnetic needle, and it was given out, that with this Mr. Bond's table, a good dipping needle, and the latitude of the place of observation, one might determine the longitude of any place in the world. *Phil. Trans.* v. viii. p. 6065. Mr. Bond was not the only projector of the kind. Messrs. Ditton, Whiston, and many others followed his example. Some were positive, others doubtful, and a few

cautious persons patiently awaited the result of experience ; but the result of actual experiments soon proved the impracticability, or the insufficiency, of the projects, which were of course gradually neglected, and were lastly even ridiculed by the facetious Dean Swift. The principal object of calculation is to determine the nature of a curve which might pass through the poles of a large magnet, and to which curve a small magnetic needle may be a tangent at any point of its course. Or, in case of the earth, to calculate the inclination which the needle must have in any particular point of its surface. The data, however, upon which these calculations must be grounded, are uncertain. The magnetic needle is acted upon by both poles of the earth, and the law of that action is by no means well known ; though it appears, both from experiments and calculation, that, most probably, the force of each pole varies in the inverse duplicate ratio of the distance. See Mr. Lambert's experiments and calculations in the *Memoirs of the Academy of Berlin* for 1756, and his second dissertation in the 22d volume of the same. We might refer our readers to other works, and we might also insert proper specimens of the calculations that have been proposed and actually made ; but since the projects are neither established upon unquestionable principles, nor are they at all satisfactory, we shall not swell this article by the introduction of intricate investigations.

In short, it appears, from the concurrence of all the most accurate experiments and observations that have been made upon land as well as at sea, 1st, that the earth is not an uniform or regular magnet, but a very irregular one ; for the ferruginous parts of it, (from the joint action of which the magnetism of the whole arises,) are irregularly disposed through it ; whence it arises, that according as the magnetic needle is nearer to or farther from any ferruginous matter, so it is more or less influenced by it. 2^{dly}, the magnetic poles of the earth are neither diametrically opposite to each other, nor indeed have philosophers as yet been able to determine their precise situations. Professor Krufft, in the 17th vol. of the *Petersburgh Commentaries*, places the north magnetic pole of the earth in lat. 70° North, and longitude 23° West of London ; and the south magnetic pole in latitude 50°

South, and longitude 92° East. Wilcke of Stockholm, in his indication chart, in the 33d vol. of the *Swedish Memoirs*, places the north magnetic pole in latitude 75° North, near Bassin's Bay, in the longitude of California, and the south pole in the Pacific Ocean, latitude 70° S. Churchman places the north pole in latitude 59° N. and longitude 135° W. and the south pole in lat. 59° S. long. 165° E. A planisphere by the Academy of Sciences at Paris for 1786, places the magnetic equator so as to intersect the earth's equator in long. 75° and 155° from the Island of Ferro, with an inclination of 12° nearly, making it nearly a great circle. But we are not informed on what authority, nor does this statement agree with the observations of the dipping made by British navigators. Mr. Churchman has given a sketch of a planisphere with lines which may be called parallels of the dip. Those parts of each parallel that have been ascertained by observation, are marked by dots, so that we can judge of his authority for the whole delineation. The magnetic equator cuts the earth's true equator in long. 15° , and 195° E. of Greenwich observatory, at an angle of 17° nearly. The circles of magnetic inclination are not parallel, being considerably nearer to each other on the short meridian than on its opposite. 3^{dly}, the magnetism of the earth, viz. the positions of its magnetic poles, magnetic equator, &c. are subject to a gradual, but uncertain variation, which, in all probability, arises from the irregular heating and cooling, from the formation and decomposition of the different internal parts of the earth, and perhaps from other causes.

Notwithstanding the failure of the advantages which were expected from the dipping property of the magnet, it must be acknowledged, that the dipping needle, which shews the above-mentioned property of the magnet, seems, upon consideration, to be the principal instrument, from the indication of which we may expect to complete the magnetic theory of the terraqueous globe : it is therefore to be wished, that accurate, and at the same time least expensive, instruments may be contrived for the purpose ; and that numerous as well as accurate observations may be made with them in every part of the world.

Discharging of Colour

DISCHARGING OF COLOUR, is frequently employed by dyers, to produce particular patterns upon the dyed stuffs. A manufacture of this kind has lately been introduced and prosecuted to great extent in the west of Scotland, for the purpose of manufacturing Bandana handkerchiefs, in imitation of those imported from India. The material of which the fabric consists is cotton, and the cloth is sometimes tweeled, and sometimes woven plain. The ground of the handkerchief is generally of the fast dye, commonly known by the appellation of Turkey red, and this colour being afterwards discharged in particular places, a number of white spots are interpersed upon the red ground. The process is by no means complex, but as the manufacture is recent, has hitherto been chiefly, if not entirely, confined to the district where it originated, and has been much admired; an account of the engine employed, and of the process, may perhaps deserve some attention. In the Indian Bandanas, the white spots are generally placed in clusters in the diagonal or diamond direction, and this distribution has been most frequently adhered to in the imitation handkerchiefs. The spots are sometimes round, sometimes square, and sometimes, though more rarely, triangular. Previous to the discovery and introduction of the discharging process, as applied to this manufacture, many imitations of the Bandanas had been made by the common mode of calico-printing. But the colours of the printed handkerchiefs, besides being less brilliant at first, were found to fade so soon, that the discharged ones do already, in a great measure, and will probably very soon entirely, supersede them.

The engine employed is a very strong press, the whole framing of which is generally of cast iron. In constructing this press, it is absolutely necessary that every part should be so strong, as to bear a very great pressure without yielding in any part. A ground plan, and transverse elevated section of it, are given in *figs. 3. and 4. Plate VIII. Miscellaneous.*

The pattern to be formed is cut upon two flat plates, which exactly correspond. They are usually of cast iron, and the lower plate is faced with copper, or some metal which will both receive a fine polish, and resist, to a great degree, the corrosive power of the discharging liquor, which is composed of a preparation of the oxy-muriate of lime diluted with water. In the under plate, which must be perfectly smooth and level, a hole is cut for every spot which is to be discharged. In the upper plate, or cover of the press, every spot is formed by a hollow tube of brass or copper, which is tightly driven into a hole formed in the plate, and cemented with a composition of white lead and oil, or any other cement, which will prevent the discharging liquor from escaping by any other passage than those through the perforated tubes.

In the ground plan (*fig. 3.*), little more of the press will be seen than the upper surface of the cover, which is distinguished by the letters A, A, A, A, placed at each corner. About the upper plate or cover is a rim to prevent the discharging liquor from running off, which is distinguished by the letters B, B, B, B.

At each corner of the plate is a round hole, working upon

a pin fastened in the under plate or sole of the press, to guide the bottoms of the perforated tubes perpendicularly over the holes in the lower plate. Besides these guides, there are two notches C, C, which grasp the upright pillars D, D, and thus the upper plate, when rising and sinking, is guided in six different places. The elevation and depression of the cover is effected by turning the screw E. The form of the upper and under plates, and the pattern being represented by *fig. 3.*, the remaining parts of the press will be more clearly seen by referring to *fig. 4.*, which is a transverse elevated section of the press, cut in the direction of the dotted line F F, *fig. 3.*

The letters of reference in *fig. 4.*, are the same for each part, as in *fig. 3.* but some parts are distinctly seen in the latter, which do not appear in the former, and these are distinguished by additional letters. As in *fig. 3.*, A A represent the upper plate or cover of the press. The rims are shewn by the letters B, B. The notches which grasp the upright pillars are marked C, C, and the pillars D, D. The screw which raises and sinks the cover of the press is distinguished by the letter E. Between the pillars D, D, is an arch of iron H H, in the centre of which is a box I, containing a female screw for working the screw E. The lower part of the screw E revolves in the socket G fixed to the cover of the press, and thus raises or sinks it as may be necessary. Upon the screw E, is fixed a wheel K K, through the arms of which is put the lever used for screwing down and raising the cover, as in other large presses. The sole or bottom of the press is distinguished by the letters L, L. It is placed exactly in a horizontal direction, and is supported by six strong iron perpendicular legs, namely, one at each corner, and the lower parts of the pillars D, D, in the middle. Between the cover and bottom, the cloth to be discharged is placed at M M.

The mechanical part of this process is, in almost every respect, entirely similar to that used by cloth dressers, bookbinders, and many other tradesmen who employ strong screw presses. To ensure the accuracy of its operation, correctness of workmanship, and strength, are all that are necessary, and these are indispensable. The press must be fixed, so that both the cover and bottom may be horizontal planes. The bottom must be perfectly level, and the perforated tubes in the cover must all exactly touch the bottom, with equal pressure. The perforation of the tubes must also correspond exactly with the holes or apertures in the bottom, and the guides must be fitted to work freely, but at the same time to prevent any aberration of the cover in rising or sinking. From the great pressure necessary when the cover is screwed down, great care ought to be taken that the whole of the supporters of the press be exactly perpendicular, and that the press, when properly placed, should be strongly secured.

The apparatus being well made and properly secured, the process of manufacture is remarkably simple. The cloth is woven of the natural colour of the cotton wool, and in this particular the manufacture, besides the beauty of its appearance, possesses a decided preference, in point of economy, over the Pullicate handkerchiefs, and other imitations of the

Indian manufacture, where the pattern is produced in the loom, and the stuff previously dyed in the state of yarn. Whatever care has been taken to prevent the tedious and repeated processes, which are used in the dyeing of Turkey red, from injuring the yarn, every person, at all conversant with the manufacture of coloured yarn, will be sensible that all the subsequent stages of the operation of forming it into cloth are much impeded by the preparatory change which it has undergone in the dyers' hands; and from the nature of the process this perhaps applies to no colour in so great a degree as to Turkey red. It follows that the wages given to winders, warpers, and weavers, must be raised in proportion to the impediments which they have to encounter, and to the smaller quantity of cloth which their exertions can of consequence produce. Besides this, all handkerchiefs ornamented in the loom, are confined to what is called *checking*; and all the various colours must be interwoven either parallel or at right angles to each other, unless very complicated and consequently expensive mounting be used. The time consumed in changing the colours of the woof also impedes, in no small degree, the speed of the operation; and thus both the state and nature of his materials, and the mechanical operation necessary to accomplish his purpose, tend at the same time to enhance the wages of the weaver, in proportion to the quantity of cloth which is the product of his labour.

But as the imitation Bandanas are woven perfectly plain, the same as calicoes, cambrics, and other stout fabrics, no impediment of this kind occurs, and the whole labour and expence are in the subsequent process, and the sum sunk in procuring the press.

After the cloth is woven, it is cleared from impurities, and dyed Turkey red, exactly in the same way as yarn is dyed. When the colour is to be discharged, the cloth is neatly folded in squares, of about 10 or 12 folds, and laid upon the sole or under plate of the press, the cover being previously elevated by means of the screw and wheel. When the cloth has been properly disposed, as at M M, the cover is brought down in contact with its upper surface, and a lever being applied to the screw and wheel, the upper and under plates are firmly screwed together, the cloth being between them. The under part of each of the perforated tubes now presses hard upon the upper surface of the cloth, and being perpendicularly over the holes in the under plate, no part of the discharging liquor can escape, excepting through the apertures which form the pattern. These apertures are distinguished in the section, *fig. 4*, by the numbers 1 to 8. The press being screwed down, the discharging liquor is poured upon the cover, and being confined by the rim passes through the apertures, and discharges the colour from those parts of the cloth which it passes through, being prevented from spreading upon any other part by the power of the screw. The discharging liquor is received into a trough placed under the lower plate of the press, and distinguished by the letter N. From this trough it is conveyed, by a spout, into vessels placed to receive it, and preserved; for although it loses much of its chemical quality in passing through the cloth and discharging the colour, it retains so much as still to be of service in many of the inferior operations of clearing and whitening of cloth. The discharge of the colour is effected by the action of the liquor in about eight or ten minutes. When the liquor has passed through, the cover of the press is raised, the cloth is taken out, and another piece being substituted, the operation goes on as before.

When two industrious persons are employed, for the purposes of folding the cloth, working the press, and applying the liquor, it is calculated, that the operation, for one piece

of 12 handkerchiefs, occupies about 15 minutes; consequently, two persons can discharge 48 or 50 dozens of handkerchiefs in one day of 12 working hours.

The operation requires only care and attention; for if the press be properly constructed, nothing more is required than to fold the handkerchiefs neatly, to lay them square upon the under plate of the press, and to be careful that the cover is tightly screwed down before the liquor is applied. When the handkerchiefs are taken from the press, the discharged spots do not appear white, but of a dull straw colour. The common operation of clearing, however, very soon gives a pure white to the spots, and adds brilliancy to the Turkey red ground. Those who have been longest in the habit of working these presses, consider a most important point to be, attention to the cement which is put where the perforated tubes are connected with the cover of the press. This certainly requires frequent and careful examination; for if any of the liquor is allowed to escape here, the ground of the handkerchiefs will be materially injured by its operation upon the colour. As the invention is recent, and the study of practical chemistry rapidly advancing, it is not improbable that some composition of superior efficacy, for this purpose, may soon be discovered. The cement used answers the purpose tolerably well, but requires great attention on the part of the person to whom the charge of the press is entrusted.

It has been already observed, that the chemical liquor generally employed is a solution of the oxymuriate of lime.

The method of preparing this liquor was discovered and first introduced into practice by Charles Tennant, esq. St. Rollochs, near Glasgow; and is, at present, universally used by those engaged in the manufactory. The following remarks, upon its practical application, have been obligingly communicated to the writer of this article by that gentleman, which he will copy in his own words:—

"Agreeable to my experiments, a solution of the oxymuriate of lime, of 1.010 specific gravity, decomposed by $\frac{1}{10}$ th part of its weight of sulphuric acid, of 1.846 specific gravity (the usual quality of marketable ore), is the most advantageous preparation for discharging Turkey red; and what, I believe, is in pretty general use with the trade in this quarter.

"As the oxymuriatic acid is but little soluble in water, when disengaged from its combination with the lime, the sooner it is used, after its separation by the sulphuric acid, the better; and this is done by simply filling the types with the solution, and allowing it to remain in them for so many minutes as proper, until the discharge is effected.

"When the discharge is completed, the acid liquor must be carefully washed out of the types previous to their being removed from their hold of the cloth."

It is hardly necessary to observe, that the word types, used by Mr. Tennant, refers to the perforated tubes fixed in the cover of the press, and previously described in the mechanical part of this article.

Some alteration in the construction of the press has very recently been introduced into some of the manufactories. The chief difference from the press represented, consists in pressing down the cover by a great weight, instead of the action of the screw. Water has been used to give this weight, and is raised into a trough upon the cover by means of a forcing pump, when the pressure is to take place. This may certainly press more equally over the whole surface of the cover than a screw, which acts only upon one point, and in this particular may be an improvement. Few of these presses have, as yet, been used; but those which have, are said to answer very well.

Distiller

DISTILLER, a person who distils spirits for sale. By 43 G. III. c. 69, every distiller or maker of low wines or spirits for sale, or exportation, within England, shall take out a licence, which shall be charged with the yearly sum of 10*l.*; and every rectifier of spirits within England shall pay for such licence a duty of 5*l.*; and such licence shall be renewed annually before the end of the year, on pain of forfeiting, if a common distiller, 200*l.*; if a molassa distiller or rectifier, 30*l.*; 24 G. III. c. 41. No person shall be deemed a rectifier or compounder who shall not have an entered still capable of containing, exclusive of the head, 120 gallons; which shall have suitable tubs and worms, and be used for rectifying British spirits for sale, 26 G. III. c. 73. By 19 G. III. c. 50. every such distiller shall cause to be put up in large characters, over the outward door of every place used for making or keeping of British-made spirits, the words *Distiller, Rectifier, or Compounder of Spirituous Liquors*, on pain of 100*l.*; and if any person shall buy any such spirits of any person not having such words over his door, he shall forfeit 50*l.* By 21 G. III. c. 55, if any distiller or dealer shall buy any British-made spirits (except, as in the former case, at the public sales of condemned spirits by the commissioners of excise) he shall forfeit 500*l.* By 19 G. III. c. 50, no person shall be permitted to make entry of any workhouse or place, or of any still or utensil for making, distilling, or keeping of low wines or spirits, unless he shall occupy a tenement of 10*l.* a year, assessed in his own name, and paying the parish rates: and by 21 G. III. c. 55, in order to prevent private distillations, every person who shall make or distil any low wines or spirits, whether for sale or not for sale, shall be deemed a common distiller for sale, and shall enter his still and vessels at the next office of excise; and every person making or keeping any wash fit for distillation, and having in his custody any still, shall be deemed a common distiller for sale, and be liable to the several duties, and subject to the survey of the officers. No common distiller or maker of low wines, spirits, or strong waters for sale, shall set up any tun, cask, wash-back, copper, still or other vessel, for making or keeping any worts, wash, low wines, spirits, or strong waters; nor alter nor enlarge the same, nor have any of them private or concealed, or any private warehouse, cellar, &c. for making or keeping any the said li-

quors, without first giving notice at the next office of excise, on pain of 20*l.*; and he in whose occupation any of the same shall be, shall forfeit 50*l.*; 8 and 9 W. c. 19. And by 24 G. II. c. 40. every distiller shall, 10 days before he distils or makes any spirituous liquors, enter every vessel, &c. at the next office of excise; on pain of 50*l.* for every still or vessel used and not entered. And every distiller shall, four days before he begins to brew any grain, &c. make entry at the next excise office, of all coppers, vessels, &c. inserting in such entry the day on which he intends to begin, and the use to which such vessel is to be applied; which shall not be altered on pain of forfeiting 100*l.* with the liquor, which may be seized by any officer of excise, 26 G. III. c. 73. And by 21 G. III. c. 55, no person shall make use of any vessel, room, &c. for making wash for the distillation of low wines and spirits, without giving notice at the next office of excise, on pain of 50*l.* for every vessel, room, &c. used without notice. Nor shall any person withdraw his entry whilst any duty is depending, or any vessels are standing, except by changing it on the day of its being withdrawn, 23 G. III. c. 70., 26 G. III. c. 73. No person is allowed to have any still or number of stills, which singly or together contain less than 100 gallons, under the penalty of 100*l.* for every still; and the wash-still shall contain at least 400 gallons, exclusive of the head, under the same penalty, 2 Geo. III. c. 5. and 14 Geo. III. c. 73.

Distillers are to shew to the officer every still or other vessel entered; and the vessels are to be marked by the gauger; and defacing the mark, or rubbing out, incurs a penalty of 20*l.* 26 Geo. II. c. 40.

Distillers who use private pipes, &c. for conveyance of distilled liquor, forfeit 100*l.* 10 and 11 W. c. 4. They shall also make holes in the breast of the still for taking gauges and samples, and provide locks on the still-heads, the holes, discharge-cocks, and furnace-door, under a penalty of 50*l.* and of 200*l.* for breaking or wilfully damaging such lock or fastening, after it has been secured by the officer, 12 Geo. III. c. 46. 14 Geo. III. c. 73.

The distiller shall provide proper ladders for the officer to examine each still, and assist in setting them up, on pain of 200*l.* 23 G. III. c. 70.

Distillers are required to give notice to the officer of excise, before they receive any wine, cider, &c. or any kind of fermented wash, on pain of 50*l.* and also before they charge or open the still, expressing and describing the number and marks of the wash-batches used; and they are prohibited from charging the still with any other, under a penalty of 100*l.* 24 G. II. c. 40; 12 G. III. c. 46; 14 G. III. c. 73.

Distillers, in preparing grist for wash, that use more than in the proportion of one quarter of wheat to two quarters of any other grain, forfeit 50*l.* 33 G. II. c. 9.

If any corn distiller, or maker of low wines or spirits from corn or grain, shall make use of any molasses, coarse sugar, honey, or any composition or extract of sugar, in brewing or preparing his wash for distillation, or receive such materials into his custody, exceeding 10lbs. in weight, he shall forfeit 100*l.*; and officers may take samples of the wash in any vessel, paying for the same at the rate of 1*s.* 6*d.* a gallon; and if the distiller shall obstruct him, he shall forfeit 100*l.* 23 G. III. c. 70.

Officers are to attend at the still-house, after due notice, to see that the wash-stills are properly filled, and when they are fully charged to lock and secure them. And if any person shall open any still-head, &c. after they have been so locked, and before they are opened by the officer of excise, or shall wilfully damage any lock or fastening, he shall forfeit 200*l.* 12 G. III. c. 46.

Removing or concealing wash, &c. in the possession of any distiller, incurs a forfeiture of the same; and such distiller, and the person employed to remove, or who shall receive the same, shall severally forfeit 10*s.* for every gallon of it; and no wort, wash, &c. shall be put into the still, or removed from the back or vessel in which it was fermented, till the same has been gauged; in the penalty of 200*l.* and double duty.

The officer shall every three months, if required, take an account of the stock of all distillers and rectifiers, and if any unfair increase shall be found, the same shall be forfeited, and may be seized; and the person in whose stock such excess shall be found shall forfeit 50*l.* Rectifiers are to mark the strength and quality of mixed spirits on the outside of the cask, and in default thereof, or if untruly marked, the same shall be forfeited, and also the cask, and may be seized; and the rectifier shall forfeit 50*l.* 26 G. III. c. 73.

By 27 G. III. c. 31, made perpetual by 41 G. III. c. 97, it was enacted, that all spirits should be deemed and taken to be of the strength indicated by Clarke's hydrometer, but by 43 G. III. c. 97, the lords of the treasury may discontinue the use of this hydrometer, and direct any other to be used in lieu of it. All British spirits of the third extraction, or which have been twice distilled from low wines, and had flavour communicated to them, shall be deemed "British brandy;" if no flavour has been communicated to them, the same shall be deemed "rectified British spirits." If of the second extraction, or once distilled from low wines, the same shall be deemed "raw British spirits." And all British spirits distilled with juniper berries, caraway seeds, anise seeds, or other seeds, or ingredients used in the compounding of spirits, shall be deemed "British compounds." And all British spirits of a greater strength than one to two over hydrometer proof, shall be deemed "spirits of wine." Officers shall take an account of the stock of rectifiers and compounders every three months at least, and if any increase of quantity, under certain limitations, be found, the quantity in excess shall be forfeited, and may be seized; and such person shall forfeit 50*l.* And if any British spirits or compounds are sent out of a greater strength than one in five under hydrometer proof, the same shall be forfeited, and treble value, or 50*l.* in the whole;

and the same may be seized, with the casks and vessels containing it. 30 G. III. c. 37. The distiller shall weekly make entry of all wash by him used for the making of low wines and spirits within each week, on pain of 10*l.*; and within a week after shall pay off the duties, on pain of double duty. 19 G. III. c. 50. All permits for removing British spirits shall correspond with the request notes, and delivered with such spirits to the buyer, on the forfeiture of the same to such buyer, and double the price including the duties; and such buyer may be admitted to prove, that such spirits were delivered without a lawful permit: but no buyer shall be allowed to avail himself of such forfeiture, unless complaint is made within fourteen days after the delivery of the spirits. 26 G. III. c. 73.

Retailers of distilled liquors, or such as sell the same in less quantity than two gallons, must take out a licence, for which they are to pay annually a sum corresponding to the rent of the premises which they occupy; if the rent of such retailer be 15*l.* or upwards, 5*l.* 2*s.*; at 20*l.* and upwards, 5*l.* 10*s.*; at 25*l.* and upwards, 5*l.* 18*s.*; at 30*l.* or upwards, 6*l.* 6*s.*; at 40*l.* or upwards, 6*l.* 14*s.*; and at 50*l.* or upwards, 7*l.* 2*s.* This licence, which is to be renewed annually, on the penalty of 50*l.*, is to be granted only to those who keep taverns, victualling-houses, inns, coffee-houses, or ale-houses; who, within the limits of the head office of excise in London, pay 10*l.* a year rent and parish rates, and in places where the occupiers are not rated 12*l.* a year; and who, in other parts of the kingdom, pay to church and poor. They must first be licensed to sell ale in the places where they dwell.

By 16 G. II. c. 8, retailers of spirituous liquors, without licence, were subject to a penalty of 10*l.*; and by 24 G. II. c. 40, all liquors found in the custody of such persons, or within six calendar months after conviction, were to be seized. And by 13 G. III. c. 56, and 30 G. III. c. 38, such retailers are to forfeit 50*l.*, subject to mitigation so as not to be reduced below 5*l.* Every person, who shall retail less than two gallons, shall enter his warehouses, shops, &c. and his spirituous liquors, on pain of 20*l.* for every place, and 40*s.* for every gallon not entered; and also the liquors and casks. 9 G. II. c. 23. 30 G. III. c. 38. By 19 G. III. c. 69, every importer or dealer in spirituous liquors, shall cause to be painted, on a conspicuous part of the house, shop, or cellar, &c. used by him, the words *Importer of, or Dealer in, Spirituous Liquors*, on pain of 50*l.* Any importer or dealer buying of a person, who has not these words over the door of his shop, &c. shall forfeit 100*l.* Any person, who hath not made entry of his liquors, and who hath these words over his door, shall forfeit 50*l.* No spirituous liquors shall be brought into a place of sale, without previous notice to the officer of excise, and leaving with him a certificate, expressing that all the duties are paid, the quantity and quality, the name of the seller, &c. on pain of forfeiting 20*l.*, and also the liquor and casks. 9 G. II. c. 23. Retailers shall not increase the quantity of their liquors, on pain of 40*s.* a gallon; and the liquors so mixed with water, or any other liquors, shall be seized and forfeited. 9 G. II. c. 23. By 21 G. III. c. 55, the stock increased shall be forfeited, a quantity equal to the increased quantity shall be seized by the officer, and the person offending shall forfeit 20*l.* The officer may, at all times, by day or night, enter into warehouses, shops, or other places, to take an account of the quantity and quality; and if any retailer hinder the officer, he shall forfeit 50*l.* 9 G. II. c. 23. No licensed retailer shall have any share in a distillery or rectifying house, or be concerned in such trade, on pain of 200*l.* 26 G. III. c. 73.

Hawkers of spirituous liquors in the streets, &c. are

liable to a forfeiture of 10*l*. 9 Geo. II. c. 23. 11 Geo. II. c. 26. Persons giving away spirituous liquors, or paying wages in them, shall be deemed retailers. 9 Geo. II. c. 23. Keepers of gaols, workhouses, &c. selling spirituous liquors, or knowingly suffering them to be sold, except such as are prescribed by a physician, surgeon, or apothecary, forfeit for the first offence 100*l*. and for the second their office. Persons bringing any such liquors into any place of that kind may be apprehended, and on conviction committed to the house of correction or prison for any time, not exceeding three months, unless they immediately pay a fine, not exceeding 20*l*. nor less than 10*l*. Debts for spirituous liquors cannot be recovered, unless they have been contracted, or the liquors delivered at one time to the value of 20*s*. or upwards: and distillers knowingly selling or delivering distilled liquors to unlicensed retailers, forfeit 10*l*. and treble their value; and the retailer, convicting the distiller, is entitled to a share of the penalty, and is himself indemnified. Persons riotously rescuing offenders, or assaulting informers, and their aiders or abettors, are guilty of felony, and liable to seven years' transportation. 24 Geo. II. c. 40. If any person shall obstruct any officer in the execution of his duty, in relation to this act, he shall forfeit 200*l*. 23 Geo. III. c. 81. No liquor exceeding one gallon shall be removed without a permit. 6 Geo. I. c. 21. British spirits made from corn are allowed on exportation as merchandize, a bounty or drawback of 3*l*. 12*s*. per ton. 5 Geo. III. c. 5. 27 Geo. III. c. 13. And by 6 Geo. II. c. 17. for spirits drawn from British corn, a drawback was to be allowed at the port of shipping, of 4*l*. 18*s*. per ton, in full of all drawbacks: and by 23 Geo. II. c. 9. there was to be an additional drawback of 24*l*. 10*s*. a ton, on all British made spirits exported; provided that they are not exported in casks containing less than a hundred gallons, and in vessels of less burden than a hundred tons, except to Africa and Newfoundland, whither they may be exported in any vessels not less than seventy tons. 6 Geo. III. c. 46. The 43 Geo. III. c. 69, which consolidates the duties, &c. of excise, continues all advances, bounties, and drawbacks, which

are particularly directed to be made by any act or acts of parliament in force, on or immediately before 5th of July, 1803, except so far as such allowances may be varied or repealed by the said act. By 39 and 40 Geo. III. c. 73. spirits distilled in England for exportation to Scotland, are exempted from the excise duties in England. And by 43 Geo. III. c. 69, for every gallon, English wine measure, of spirits, not exceeding in strength that of one to ten over hydrometer proof, and so in proportion for any higher degree of strength, made in England and thence imported into Scotland, payment is to be made by the importer before landing, of 4*s*.; and by c. 81. an additional duty of 2*s*.: for every such gallon manufactured in Scotland and brought from thence into England, 5*s*. 0½*d*.; and by c. 81. an additional duty of 2*s*. 5*d*. For every gallon of such spirits of greater strength than one to ten over hydrometer proof, and not exceeding 3*l* per cent. over and above one to ten over hydrometer proof, 7*s*. 5½*d*. and a surcharge. And all duties and drawbacks under these acts shall be proportionate to the actual quantity. No spirits shall be sent from Scotland to England, or from England to Scotland by land, or in vessels of less than 70 tons burden, or in casks containing less than 100 gallons, on forfeiture of the same, together with casks or package; and also the vessels, boats, horses, cattle, and carriages employed, which may be seized. 28 Geo. III. c. 46. And if any distiller, rectifier, compounder, or dealer in spirits, or servant belonging to any such person, shall obstruct any officer in the execution of this act, he shall forfeit 200*l*.

DISTILLERY, the art of distilling brandy and other spirits. This art was first brought into Europe by the Moors of Spain about the year 1550: they learned it of the African Moors, who had it from the Egyptians; and the Egyptians are said to have practised it in the reign of the emperor Dioclesian, though it was unknown to the ancient Greeks and Romans. Anderson's Hist. of Commerce, vol. i. p. 83. See FERMENTATION, and MALT Distillery.

Docks

Docks, probably from *δοχίον*, *receptaculum*, of *δέχομαι*, *I receive*, are artificial basins, or excavations, under different denominations, formed for the convenience of receiving ships, in rivers and harbours, for the purpose of repairing, or for loading and unloading their cargoes, out of the influence of the tide. They are constructed of brick, stone, or timber; with locks or flood-gates, pointed to or from the tide, to keep the water in or out, as the object and nature of the docks require.

Wet Docks are for the reception of ships to lie afloat while loading or unloading, with gates pointed from the tide, to keep the water in at low water. Locks are attached thereto, with double gates, for the more easy admission and egress of shipping, without losing more water than necessary; and to aid the operation of opening and shutting these gates,

sluices are made within the same, to regulate the water within the locks, until the same level is produced within as without, so that the gates may open with facility.

Dry Docks are of various kinds,

1. Basins, or docks open to the tide, are called *dry docks*, because the vessels frequenting them ground at low water, and lie dry on the ebb tide, and float again on the next rise of the tide. They are used at Liverpool as entrances to the wet docks, and are frequented by coasters, and small or light vessels, that do not injure by lying on the shore.

2. *Graving Docks*, for repairing of ships, are excavations with flood-gates pointed towards the tide, to keep the water out while ships are under repair. Vessels are admitted at high water, and the gates are shut at low water; and when

the repairs are completed, the gates are again opened before the rise of the tide, and the vessel is on the flood hauled out of dock. In some countries, where there is little or no tide, these docks are so constructed, as to have the water within forced out by pumps, or other mechanical operations, as in Russia and other parts.

In some places, as at Portsmouth, floating gates are constructed, in the form of a vessel, with each end like the bow of a ship, neatly fitted to the lock, and to work up or down a groove in the lock with the tide, by pumping water into, or out of the vessel, sufficient to float or sink it, as occasion might require. A vessel of this kind was also used at the London docks, to keep the water out while they were making.

3. *Slips* for the building of ships, may be classed under this head. They also are excavations, sloping and inclined towards the tide, well framed and floored with timber, &c. Ships, when built, are generally launched at spring tides, by driving away the shoars and props which supported them, when they are easily launched from off the slips.

Naval Docks.—Portsmouth, Plymouth, Chatham, Sheerness, Woolwich, and Deptford, are the principal naval arsenals of Great Britain; where ships of war of every description from sloops to ships of the line of 130 guns, are built and repaired, and when finished are turned out of dock: other countries have similar establishments.

Commercial Docks.—The convenience and advantages of wet docks for the security of shipping and the dispatch of business are become objects of great attention in many countries for commercial purposes. The adoption of them within this last century has been no where more general than in Great Britain. The docks now made and making, at London, Liverpool, Hull, Bristol, Leith, &c. have contributed, and will greatly contribute (combined with our natural advantages) to the increase of our commerce, wealth, and population. They have formed our great leading ports into depots, and have given, aided by the extension of the bonding system, great facilities to commerce by suspending, in many cases, the payment of duties until goods are taken out for home consumption. Docks, while giving protection, convenience, and dispatch to commerce, shipping, and revenue, happily link and unite, by means of rivers, roads, and canals, our foreign with our domestic commerce.

Liverpool Docks.—The port of Liverpool, from the badness of its harbour, the rapidity of the Mersey, and the shifting of its sands, was obliged, at an early period, to resort to docks: for this purpose an act was passed in 1708. What necessity first dictated, has since been one of the principal causes of the town becoming, through the enterprising spirit and industry of its inhabitants, the second port in the

kingdom, for commerce, size, and population. In the course of one century there have been established within that port, five wet docks, three dry docks, and five graving docks, independent of the duke of Bridgewater's dock, for canal purposes; and a plan is now in execution for making two additional wet docks, and enlarging Queen's dock, which is proposed to be connected with the Mersey by means of a new floating dock, and a dry harbour basin. Almost all these docks are, more or less, encroachments on the banks of the river.

By the act passed in 1708, authority was obtained to make the first dock and basin for the security of shipping and the loading and unloading of the same. The management of the undertaking was invested in the corporation for the term of 21 years, which gave for this purpose four acres of land, and they were empowered to borrow the sum of 6000*l*. In 1717, the term was prolonged for 14 years, and they were authorized to borrow 4000*l*. more. In 1737, the term was further extended to 31 years, and powers given to make an additional dock, to build a pier in the open harbour, and to light the docks. The corporation on this occasion gave seven acres of land, and they were empowered to borrow 6000*l*. In 1761, the commerce of Liverpool was so much increased, and its shipping had become so numerous, and so enlarged in size, that further accommodation was wanting. The term of the corporation's management was again extended for 21 years, with powers to make another dock, and to erect a light-house for the benefit of the port; for these purposes they were authorized to borrow the sum of 25,000*l*., and to raise the further sum of 2000*l*. on the light-house duties. In 1784, the powers of all the former acts were enlarged, and the term extended to 41 years, with liberty to make two additional docks and piers, and to borrow for this purpose 70,000*l*. In 1799, an act was passed to alter and enlarge the powers of former acts, and to render the docks and the port more commodious and safe; by which a further extension of term was granted for 30 years. The corporation again gave some lands, and they were empowered to make two additional docks, and other docks; with liberty to raise the sum of 120,000*l*., and to double the former tolls.

Under the authority of these various acts of parliament the several docks have been constructed, and it has been found that each successive improvement, by affording additional convenience to foreign trade, has been followed by its increase, and prepared the way for the further extension of this excellent system of accommodation at future periods. The names and dimensions of the docks are as follows, and a plan is annexed on a scale of double the size of the plan of the docks for London. See *Plate of Docks*.

Docks.		Long.	Broad.	Area.	Stat. Mea.	Dock Gates.		Quay.
						Broad.	Deep.	
No.		Yards.	Yards.	Square Yds.	A. R. P.	Feet.	Feet.	Yards.
1	Old Dock - - -	200	70 to 90	17,070	3 2 4	34	23	652
2	Salthouse - - -	irregular.		22,420	4 2 21	34	23	640
3	George's - - -	250	100	26,068	5 1 2	38	25	670
4	King's - - -	290	90	25,650	5 1 8	42	25	715
5	Queen's - - -	270	130	33,600	6 3 31	42	25	780
Basins.				124,808	25 2 26			
6	To the Old Dock - - -	-	-	19,298	3 3 34			
7	To George's Dock - - -	-	-	12,090	2 3 0			
8	To King's and Queen's Docks - - -	-	-	14,420	2 3 37			
				170,616	35 1 17			

These wet docks are all for ships from foreign voyages. The dry docks are for coasters, and other small and light vessels. There are five graving docks, which are from 390 to 490 feet long, and hold two or three vessels for repair, at a time. No. 9. The duke of Bridgewater has a dock at Liverpool, connected with his canal concerns, calculated to hold 42 canal flats, of 50 tons, such as No. 10 in *Plate of Docks*.

The docks are surrounded with convenient and spacious warehouses for the reception of goods; and a tobacco-warehouse capable of containing 7000 hogheads.

The several docks are connected with each other by means of tunnels or sluices under ground, for the purpose of scouring them when they want cleansing. This is effected by letting the water off from any one of them, and opening the sluices into it in different directions; while a number of men with shovels throw the mud into the currents, which is thus washed into the river, and in the course of about 12 or 14 days the dock is sufficiently cleared.

Accurate tide tables are kept, from which it appears that the rise of the tide in the river is about 30 feet at spring tides, at which times there are about 20 feet water at the Salt-house dock gates, and two feet more at the other dock gates.

The corporation make all necessary regulations relating to the docks; and the accounts of the receipt and expenditure are annually examined and published by commissioners unconnected with the corporation. Ships are here discharged by their own crews, but cooking on board is not permitted, and all lights must be put out at stated hours.

It cannot be doubted that the docks have greatly encouraged the increase which has taken place in the trade of Liverpool, and by their future enlargement, or the formation of additional ones, the port will readily accommodate the future increase of its commerce to any possible extent. In the year 1571, the inhabitants, addressing queen Elizabeth, styled the place the poor decayed town of Liverpool; and in fact, about that period it was only a little fishing town, having 12 barks, whose tonnage amounted to 223 tons, and which employed only 75 men. In the year 1805, the number of British built ships belonging to the port of Liverpool was 741, and their tonnage amounted to 111,227 tons: the tonnage of the ships which entered the docks in that year was 463,482 tons.

Statement of the amount of the dock duties at different periods: each year ending 24th. June.

Years.	Ships.	Duties.		
		£.	s.	d.
1755	—	2,417	13	11
1760	1245	2,330	6	7
1765	1930	3,455	8	4
1770	2073	4,142	17	2
1775	2291	5,384	4	9
1780	2261	3,528	7	9
1785	3429	8,411	5	3
1790	4223	10,037	6	2½
1795	3948	9,368	16	4
1800	4746	23,379	13	6½
1805	4618	33,364	13	1
1808	5225	40,688	0	0

The tonnage of the ships which entered the docks in the year ending 24th June 1808, amounted to 516,836 tons.

London.—When it is considered that the port of London commands about three-fifths of the commerce of the whole kingdom, that it has frequently riding within it from 1300 to 1400 sail of vessels at a time, and in the course of the year

about 14,000; that from the year 1700 to 1792 its imports had increased from 4,785,538*l.* to 12,072,674*l.* and its exports from 5,387,787*l.* to 14,742,516*l.*, it appears surprising that proper accommodations for its commerce should have been so long wanting. The legal quays, which were only 1464 feet long, having remained the same as at the time of the fire of London, in the year 1666, were, with the aid of the sufferance wharfs, totally inadequate to the increase of its commerce. The inconveniences arising from the crowded state of the Thames at all times, but particularly at those periods when ships arrive in large fleets, were long felt and complained of by all the principal merchants; and from reference to the reports of committees, and other publications on the improvement of the port of London, it appears that different plans had been frequently suggested to extend the convenience of the legal quays both above and below London bridge. It was not, however, till the year 1793, that a plan was first projected for making wet docks for the port of London, in Wapping, the isle of Dogs, and at Rotherhithe, and the preference intended to have been given, in the first instance, to Wapping, from its vicinity to the city, the seat of business, and to the custom-house; one end of the spot fixed upon being within a quarter of a mile of the Tower of London, and the eastern extremity of it about one mile. The plan of docks meeting with approbation and encouragement, they were circulated generally to all the great leading interests in and out of parliament, and to all the principal persons connected with the commercial interest.

In 1794, a general meeting of merchants was convened, to consider the great inconveniences of the port of London, arising from the crowded state of the river, and the confined extent of the legal quays; when a committee was appointed to consider of the best mode of relief, who took into consideration all the plans which had been suggested, when they approved of the plan for making wet docks in Wapping with wharfs and warehouses on their borders, as the most effectual means of remedying the evils of the port. In consequence of this determination, Mr. Daniel Alexander, an ingenious architect and surveyor, who had been making great alterations at Rochester bridge, and who was conversant with operations connected with the tide, was directed to make a survey, and prepare plans and estimates for forming docks at Wapping, with the addition of a cut or canal leading to them, from that part of Blackwall where the present East India docks have been made, and along a line where the West India docks have been since formed. The plans and estimates were laid before a general meeting of merchants on 22d December, 1795, when they were unanimously approved, and a subscription of 800,000*l.* was filled in a few hours, for carrying the same into execution. A committee was appointed to make application to parliament, who presented a petition in January 1796, which was referred to a select committee of the house of commons, who were directed “to enquire into the best mode of providing sufficient accommodation for the increased trade and shipping of the port of London.”

The application of the merchants experienced great opposition both from the corporation of the city of London and from private interests; and a great variety of plans and projects were brought forward for the extension of the legal quays above and below the bridge, and the improvement of the river, with or without docks. This caused much delay, but the necessity of providing some additional accommodation for the increasing multitude of ships which filled the river became every day more evident; and, upon a comparison of the various plans for making docks in different situations, it was generally admitted, that wet docks might be formed in various situations at a much less expence than on the spot fixed upon for the London docks at Wap-

ping, but that the situation of the latter, from its vicinity to the seat of commerce, would much more than counterbalance the additional expence of their formation. Through the great exertions and perseverance of William Vaughan, esquire, assisted by other highly respectable mercantile characters, the various obstacles to the plan of the London docks were successively overcome, and in August 1798, the subscribers gave notice, that in the ensuing session of parliament they meant to renew their application for forming docks at Wapping, and in December following they petitioned for leave to bring in a bill for this purpose. A few days after a petition was presented by the corporation of London, with a view to similar objects, and by making a navigable canal or passage across the isle of Dogs from Blackwall to Limehouse, purchasing the mooring-chains in the river, which were mostly private property, and appointing harbour-masters to regulate the navigating and mooring of vessels in the port; they also proposed to make wet docks in some part of the isle of Dogs for the reception and discharge of West India shipping. The latter part of the plan had however been taken up by a number of West India merchants and planters, who had formed themselves into a company distinct from the subscribers to the London docks, for the purpose of forming docks for the reception of the West India trade only, either alone, or in conjunction with the other improvements projected by the corporation. The general conviction of the necessity of some measure of this kind was not sufficient to produce a union of interests in favour of either of the proposed plans; at length the committee of the house of commons made a report, recommending the formation of wet docks as the only remedy for the evils of the port, and that they should be made both at Wapping and the isle of Dogs, but that the latter should be adopted first.

The corporation of London and the West India merchants forming a junction, the act for making the West India docks passed in July 1799. In the next session, on the 30th June 1800, an act was passed for forming the docks at Wapping, and another act has since been passed for making docks at Blackwall for the East India trade. These several undertakings, all arising out of the original project of the London docks, have been since carried into execution, to the great convenience of the commerce of the port of London, and the permanent benefit of the subscribers, by whom the large sums necessary for accomplishing them were advanced. For some particulars of the progress of their formation, see THAMES river, under the article CANALS.

West India Docks.—The act for establishing the West India Dock Company, was passed 12th July 1799. Their original capital was 500,000*l.*, which they were empowered to increase to 600,000*l.* This capital was, however, found insufficient for completing the undertaking, and in 1802 the company were authorised to add 200,000*l.* to it, making their capital 800,000*l.* which has been since increased to 1,200,000*l.* The dividends to be paid thereon to the subscribers, are not to exceed 10 *per cent. per annum*, to which rate they have already attained.

The concerns of the company are under the management of twenty-one directors, eight of whom are chosen by the corporation of London, four of them being aldermen, and four common-council men.

The works were begun 2d February 1800, and the first ship entered the homeward-bound dock on 27th August 1802. The homeward-bound dock, see *Plate N. fig. B. 1.* which is 2650 feet long, and 500 feet broad, is estimated capable of holding 300 sail of vessels of 300 tons and upwards each. The outward-bound dock, B 2, is 2600 feet long, and 400 feet broad. They both communicate by means of

locks at the end (next Blackwall) with a basin of about six acres, with sloping banks, which is connected with the river by the entrance lock; and at the end next Limehouse, where there is another basin of about two acres, built of brick, through which all vessels go out, which have occasion to go into the river to repair. The two docks are separated and surrounded by strong walls.

The use of these docks is limited to the West India trade for 21 years. The company take the ships under their sole direction, of unloading and management from the moment they enter the docks, discharging the same by their own servants; when the crews are dismissed, and neither cooking nor residence allowed on board any of the vessels while they remain in the homeward-bound docks, the gates of which are shut every evening at stated hours. A military guard is stationed without the docks day and night. The distance from the standard in Cornhill, to the nearest dock gates, is rather more than three miles, and to the further extremity of the dock wall, about half a mile more; a considerable expence of cartage is unavoidably incurred, by the ships discharging at this distance, but there is an excellent road both to these docks, and to the East India docks.

Both the docks and warehouses are handsome and spacious, the whole forming a noble and interesting object, which must impress every one with an idea of the vast magnitude of the branch of commerce, to which they are appropriated. The warehouses on the north and west sides, are ten in number, with partition walls up to, but not through the roof, and are capable of containing 8000 hogheads of sugar each; on the south side are extensive warehouses for rum. The docks were planned and executed by William Jessop, esq. civil engineer, and the warehouses by Mr. Gwyllt, surveyor and architect.

Under the West India dock act, the corporation of London were empowered to make a canal from Limehouse to Blackwall, of about three quarters of a mile in length, to save the navigation round the Isle of Dogs, which has been completed, and may probably at some future period be converted into a dock. See *Plate of Docks, fig. D.*

London Docks.—The act for establishing this company was passed 20th June 1800. Their original capital stock was 1,200,000*l.*, and they were authorised to borrow, at interest, the further sum of 300,000*l.*; but a larger capital being found necessary for completing the undertaking, they applied to parliament, in 1804, for leave to augment their capital stock by 500,000*l.*; and having since obtained another act for the liberty of raising a further sum of 500,000*l.*, the total capital stock the company are now authorised to raise, if it shall be found necessary, is 2,200,000*l.* The dividends to be paid thereon to the subscribers, are limited to 10 *per cent. per annum*. The management is vested in 24 directors, elected annually, of whom the lord mayor is one.

The original plan of these docks (with the canal, which had been abandoned) was submitted by the directors to the consideration of four civil engineers of the first eminence and respectability, viz. Messrs. Robert Mylne, John Rennie, Joseph Huddart, and William Chapman, and underwent some alterations by them. The dock and basin, as altered by them, were then executed under the direction of Mr. Rennie, and the warehouses and wall by Mr. Alexander.

The dock, basin, and warehouses, which are completed, are of brick and stone, are well designed, in a chaste and grand style, and happily executed, producing a noble effect. The length of the dock, as in *Plate of Docks, fig. A. 1.* is 1260 feet long, and 690 feet broad, containing 20 acres, and the basin marked A. 2. is three acres, and the whole capable of containing about 230 ships of 300 tons burthen and upwards.

In the act a power was preserved to make a second dock and basin to the eastward, with an entrance at Shadwell, containing an area of 14 acres, as denoted in the plan marked A 3 and 4. There are at present, on the north side of the dock, five stacks of warehouses furnished with party and cross sub-divisionary walls through the roofs, as a further protection against fire. On the south side are other warehouses, besides vacant spaces left in different parts of the premises for additional warehouses. On the east side is the tobacco warehouse, planned to contain 24,000 hogheads of tobacco, and spacious arched vaults underneath for wine and tobacco. The latter are now wholly appropriated to wine, and hold many thousand pipes. The whole building stands upon an area of near five acres, covering more ground, under one roof, than any public building or undertaking, except the pyramids of Egypt. Its roof is light, airy, and simple, and adds greatly to the beauty and boldness of the design, and stands unrivalled in architectural buildings of its kind.

The company was required to complete the docks within seven years, which was afterwards extended to twelve years. On the 24th January 1805, they gave notice, by advertisement, that the basin at Bel-dock, and the dock communicating therewith, and also part of the warehouses, vaults, and quays, were ready for the reception of ships and landing their cargoes, in consequence of which the dock was opened for public use in the following week.

All ships laden with wine, brandy, geneva, and other spirits, tobacco, and rice, must unload in these docks for the term of twenty-one years; with all other vessels the use of the docks is optional, excepting those from the East and West Indies. The ships discharge their cargoes under the company's cranes, by their own crews. In these docks, cooking and residence on board are allowed, but no lights are permitted after certain hours. The whole is surrounded by a wall, the gates of which are shut at stated hours.

There is a neat swivel cast-iron bridge over the entrance lock at Wapping, and an excellent double steam-engine erected, which was used while the docks were making, to carry off the water; it is not now worked.

The rise of the tide at the entrance lock of the basin, is four feet lower than the dock itself.

East India Docks.—The act for establishing the company passed 27th July 1803. Their original capital was 200,000*l.* divided into shares of 100*l.* each; and they were authorized to increase the capital to 300,000*l.* if it should be found necessary. In 1806 they were empowered to add 100,000*l.* more to their capital, making with the former sum 400,000*l.*, nearly the whole of which has been raised. The dividends to be paid thereon to the subscribers, are, as in the two preceding companies, limited to 10 *per cent. per annum*. The concern is under the management of 13 directors, who must be holders of at least 20 shares of the company's stock, and four of them must be directors of the East India company.

The first stone of these docks was laid in March 1805, and the first ship entered them in August 1806. The dimensions of the dock for unloading inwards are 1410 feet in length, and 560 feet in width, containing about 18½ acres: the dock for loading outwards, which was a part of Mr. Perry's dock, is 780 feet in length, and 520 feet in width, containing 9½ acres. The extent of the entrance basin, which connects them with the river, is 2½ acres; the length of the entrance lock 210 feet, the width of the gates 48 feet in the clear, and the depth of water at ordinary spring-tides 24 feet. See *Plate N. C. 1. 2.*

These docks are appropriated solely to the reception of East India shipping, and the company undertake to deliver the whole of the cargoes. No cooking, fire, or residence on board, are permitted in these docks, the gates of which are shut every afternoon at four o'clock. The distance from the East India warehouses being about four miles, the goods are conveyed thither in caravans of a particular construction, by an excellent road, towards the formation of which 10,000*l.* was contributed by the company.

Perry's Dock at Blackwall, and *Greenland Dock* on the opposite side of the river, were private property, having been formed by enterprising individuals, long before any public accommodation of this kind existed in the port of London. The first now forms one of the East India docks; and Greenland dock, hitherto appropriated to the purposes of the whale fishery, has likewise been purchased by a company.

The Surrey canal company have a dock at the entrance of their canal for small vessels, and have raised a considerable capital.

It affords a striking proof of the wealth and prosperity of the city of London to find, that in the course of about ten years, there has been expended a capital of between four and five millions in these great undertakings for providing accommodation and security to its shipping and commerce.

Hull Dock, is situated on the Humber, and was formed under the authority of an act passed in 1774. It is about 480 yards long, and 88 yards wide, containing nearly 10 acres, and will accommodate about 130 vessels at a time. The original capital of the company consisted of 120 shares, which have since been increased to 180 shares. It has been a most profitable concern to the subscribers, as they have usually made a large dividend; this, however, has varied very considerably: in the year 1806 they divided 72*l.* 15*s.* 10*d.* *per share*; but in 1807, after having admitted 25 new shares, the dividend was only 49*l.* 9*s.* 1*d.* *per share*. The formation of another dock, with other improvements, has been undertaken.

Bristol.—Bristol, with a large trade carried on in an inconvenient harbour from the great height of its tides, has, at length, undertaken an extensive plan, according to which a very capacious wet dock is to be formed by damming up the river Avon for about two miles of its length, and turning the river into a new cut which has been formed to receive it.

Other ports, such as Lancaster, Grimsby, Dover, and Margate, &c. have their docks or piers for the safety and accommodation of the shipping frequenting them.

At *Leith*, in Scotland, a large range of docks are making on an extensive scale, which are to be capable of receiving the men of war which may frequent that part of the coast, the old harbour having been found very inadequate: one of the docks is already completed, and a dry dock is nearly so. From Leith being within one mile of Edinburgh, and the spirit of improvement prevailing in Scotland, there is every probability of these docks and the intended inclosed harbour being executed on an extensive and judicious plan, and becoming of much public utility.

On the continent, several ports, such as Havre, Ostend, &c. have wet docks on an extensive scale, under various regulations.

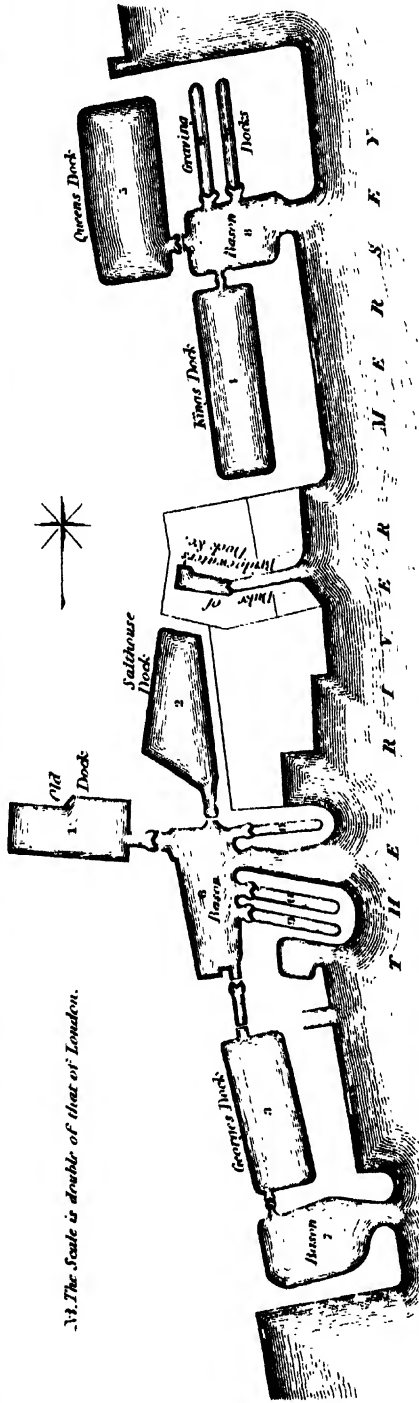
Dock-Yards, are magazines of all sorts of naval store, and timber for ship building; the royal dock-yards in England, are those at Chatham, Portsmouth, Plymouth, Woolwich, Deptford, and Sheerness. In time of peace, ships of war are laid up in these docks, those of the first rates mostly at Chatham, where, and at other yards, they receive, from time to time, such repairs as are necessary.

These yards are generally supplied from the northern crowns, with hemp, pitch, tar, rosin, canvas, oak-plank, and several other species. But as for masts, particularly those of the largest size, they have been usually brought from New England.

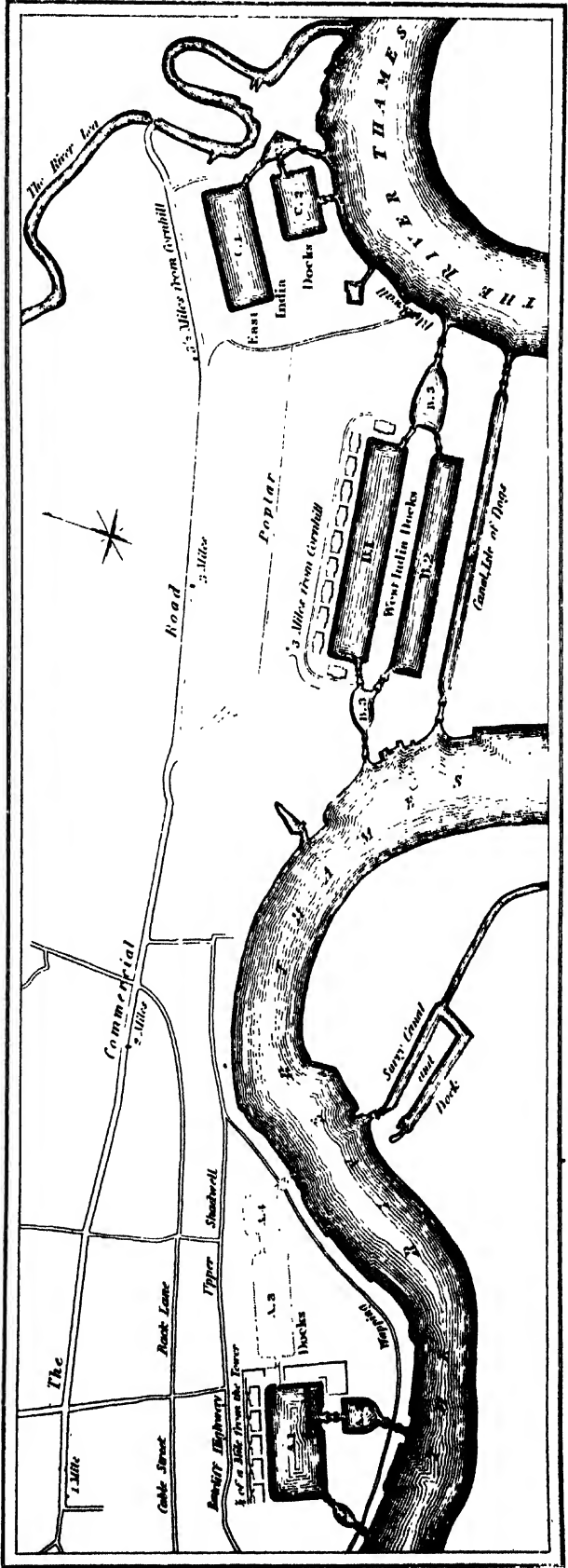
The principal dock-yards are governed by a commissioner,

resident at the port, who superintends all the musters of the officers, artificers and labourers, employed in the dock-yard and ordinary. He also controuls their payments ; examines the accounts ; contracts and draws bills on the navy-office to supply the deficiency of stores, and regulates whatever belongs to the yard, maintaining due order in the respective offices.

PLAN OF THE DOCKS AT LIVERPOOL, IN 1808.



PLAN OF THE DOCKS AT LONDON, IN 1808.



Draught

'DRAUGHT', in *Architecture*, is the representation of a building delineated on paper, explaining the various parts of the exterior and interior by means of plans, elevations, and sections drawn to a scale, by which all the parts are represented on a plane in the same proportions of the different sides of the intended edifice, or, at least, the proportions may be ascertained from these drawings. The extent of the building, with regard to its horizontal dimensions, is ascertained by means of plans. The dimensions of the vertical faces are generally obtained by the elevations and sections, and always when the plane of delineation is parallel to these faces. The vertical dimensions of buildings, upon circular and polygonal plans, must be found partly from the plans, and partly from the elevations or sections. Over and above general plans, elevations, and sections in complex buildings, a set of drawings, shewing the detail of the smaller parts, will be necessary.

Besides these drawings, which are used in the conducting of the work, perspective representations for the use of the proprietor will also be necessary, in order that he may form a just idea of the edifice which he intends to rear in one or more points of view.

When the several stories of a building differ in their construction, each story requires a separate plan. The section is generally taken, parallel to one of the sides of the edifice, through the most complex part of it. In this the stair-case is commonly shewn. Most buildings require, at least, two sections; some many more. When the sides of a building are dissimilar, as many elevations will be required as there are sides.

The number, the form, and the dispositions of rooms, are shewn by the plans.

He who gives the several designs of a building ought to be well acquainted with the nature of its fabrication, or of construction in general, before he commits his ideas to paper, and to the examination of the public, or otherwise he will be liable to censure.

DRAUGHT-HORSE. See HORSE.

DRAUGHT, in *Mechanics*, the force or power necessary to move any machine, as a horse-mill, waggon, cart, plough, &c. For accurately and conveniently ascertaining the draught of (or power exerted by) horses, oxen, men, &c. in drawing, as also for determining the direct pull or strain on any rope, chain, &c., various machines have been invented, some of which we propose to describe under the article **DYNAMOMETER**, which see.

DRAUGHT, in *Medicine*. See POTION.

DRAUGHT, in *Painting*, &c. See DESIGN.

DRAUGHT, in *Trade*, is an allowance made in the weight of commodities; the same as clough.

DRAUGHT, is also used sometimes for a bill of exchange, and commonly for an order for the payment of any sum of money, due, &c. Then the person who gives the order is said to draw upon the other.

DRAUGHT, *reduction of a*. See REDUCTION, and PENTAGRAM.

DRAUGHT-Compasses, those provided with several moveable points, to draw fine draughts in architecture, &c. See COMPASS.

DRAUGHT and Cording of Looms, signifies, among *Weavers*, the art of adapting those parts of a loom which move the warp, to the formation of various kinds of ornamental figures upon cloth. In every species of weaving, whether direct or cross, the whole difference of pattern or effect is produced, either by the succession in which the threads of warp are in-

roduced into the heddles, or by the succession in which those heddles are moved in the working. The heddles being stretched between two shafts of wood, all the heddles connected by the same shafts are called a leaf, and as the operation of introducing the warp into any number of leaves is called drawing a warp, the plan of succession is called the draught. When this operation has been performed correctly, the next part of the weaver's business is to connect the different leaves with the levers or treddles by which they are to be moved, so that one or more may be raised or sunk by every treddle successively, as may be required to effect the pattern required. These connections being made by coupling the different parts of the apparatus by cords, this operation is called the cording. In order to direct the operator in this part of his business, especially if previously unacquainted with the particular pattern upon which he is employed, plans are drawn upon paper, specimens of which will be found in *Plate XII. Miscellany*. These plans are horizontal sections of a loom, the heddles being represented across the paper at A, and the treddles under them, and crossing them at right angles at B. In *figs. 1 and 2*, they are represented as distinct pieces of wood, those across being the under shaft of each leaf of heddles, and those at the left hand the treddles. In actual weaving, the treddles are placed at right angles to the heddles, the sinking cords descending perpendicularly, as nearly as possible, to the centre of the latter. Placing them at the left hand therefore, is only for ready inspection, and for practical convenience. At C, a few threads of warp are shewn as they pass through the heddles, and the marks denote the leaf with which each thread is connected. Thus in *fig. 1*, the right-hand thread, next to A, passes through the eye of a heddle upon the back leaf, and is disconnected with all the other leaves; the next thread passes through a heddle on the second leaf; the third through the third leaf; the fourth through the fourth leaf, and the fifth through the fifth or front leaf. One set of the draught being now completed, the weaver again begins with the back leaf, and proceeds in the same succession again to the front. Two sets of the draught are represented in this figure, and the same succession, it is understood by weavers, (who seldom draw more than one set,) must be repeated until all the warp is included. When they proceed to apply the cords, the left hand part of the plan at B serves as a guide. In all the plans upon this plate, excepting one which shall be noticed, a connection must be formed by cording between every leaf of heddles and every treddle; for all the leaves must either rise or sink. The raising motion is effected by coupling the leaf to one end of its correspondent top lever; the other end of this lever is tied to the long march below, and this to the treddle. The sinking connection is carried directly from under the leaf to the treddle. To direct a weaver which of these connections is to be formed with each treddle, a black spot is placed when a leaf is to be raised, where the leaf and treddle intersect each other upon the plan, and the sinking connections are left blank. For example, to cord the treddle 1. To the back leaf put a raising cord, and to each of the other four sinking cords. For the treddle 2, raise the second leaf, and sink the remaining four, and so of the rest; the spot always denoting the leaf or leaves to be raised. The *figs. 1 and 2* are drawn for the purpose of rendering the general principle of this kind of plans familiar to those who have not been previously acquainted with them; but those, who have been accustomed to manufacture and weave ornamented cloths, never consume time by representing either heddles or treddles as solid or distinct bodies. They content themselves with ruling a number of lines across a piece of paper, sufficient to make

the intervals between these lines represent the number of leaves required. Upon these intervals, they merely mark the succession of the draught, without producing every line to resemble a thread of warp. At the left-hand they draw as many lines across the former as will afford an interval for each treddle, and in the squares, produced by the intersections of these lines, they place the dots, spots, or cyphers, which denote the raising cords. It is also common to continue the cross lines, which denote the treddles a considerable length beyond the intersections, and to mark, by dots, placed diagonally in the intervals, the order or succession in which the treddles are to be pressed down in weaving. The former of these modes has been adopted in the remaining plan, upon the plate, but to save room the latter has been avoided, and the succession marked by the order of the figures under the intervals which denote the treddles.

Some explanation of the various kinds of fanciful cloths, represented by these plans, may serve further to illustrate this subject, which is, perhaps, the most important of any connected with the manufacture of cloth, and will also enable a person, who thoroughly studies them, readily to acquire a competent knowledge of the other varieties in weaving, which are boundless. *Figs. 1 and 2* represent the draught and cording of the two varieties of tweeled cloth wrought with five leaves of heddles. The first is the regular or run tweel, which, as every leaf rises in regular succession, while the rest are sunk, interweaves the warp and woof only at every fifth interval, and as the succession is uniform, the cloth, when woven, presents the appearance of parallel diagonal lines, at an angle of about 45° over the whole surface. When there is no other figure upon the cloth, and the fabric is fine, this produces a very pleasing effect, and is much used, especially in the manufacture of silks of various descriptions. Tweeling is also much employed in the coarser descriptions of cloths made from every kind of material employed in the manufacture. In the linen, it is used for sheeting and many other kinds of household cloths which require durability. Many of the stronger kinds of woollen cloths are also tweeled. Goods are manufactured in very great variety in Lancashire from cotton, and many kinds of fanciful tweeling introduced. A tweel may have the regularity of its diagonal lines broken, by applying the cording as in *fig. 2*. It will be observed, that in both figures the draught of the warp is precisely the same, and that the whole difference of the two plans consists in the order of placing the spots denoting the raising cords, the first being regular and successive, the second alternate.

Figs. 3 and 4 are the regular and broken tweels which may be produced with eight leaves. This properly is the tweel denominated *sattin* in the silk manufacture, although many webs of silk, wrought with only five leaves, receive that appellation. Some of the finest Florentine silks are tweeled with sixteen leaves. When the broken tweel of eight leaves is used, the effect is much superior to what could be produced by a smaller number, for in this two leaves are passed in every interval, which gives a much nearer resemblance to plain cloth than the others. For this reason it is preferred in weaving the finest damasks. The draught of the eight leaf tweel differs in nothing from the others, excepting in the number of leaves. The difference of the cording in the broken tweel will appear by inspecting the cyphers which mark the raising cords, and comparing them with those of the broken tweel of five leaves. *Fig. 5* represents the draught and cording of striped dimity of a tweel of five leaves. This is the most simple species of fanciful tweeling. It consists of ten leaves, or double the number of the common tweel. These ten leaves are moved by only five treddles in

the same manner as a common tweel. The stripe is formed by one set of the leaves flushing the warp, and the other set the woof. The *fig.* in the *Plate* represents a stripe formed by ten threads, alternately drawn through each of the two sets of leaves. In this case, the stripe and the intervals will be equally broad, and what is the stripe upon one side of the cloth, will be the interval upon the other, and *vice versa*. But great variety of patterns may be introduced by drawing the warp in greater or smaller portions through either set. The tweel is of the regular kind, but may be broken, by placing the cording as in *fig. 2*. It will be observed that the cording marks of the lower or front leaves, are exactly the converse of the other set; for where a raising mark is placed upon one, it is marked for sinking in the other; that is to say, the mark is omitted; and all leaves which sink in the one, are marked for raising in the other: thus one thread rises in succession in the back set and four sink, but in the front set four rise and only one sinks. The woof, of course, passing over the four sunk threads, and under the raised one, in the first instance, is flushed above; but where the reverse takes place, as in the second, it is flushed below, and thus the appearance of a stripe is formed. The analogy subsisting between striped dimity and dornock is so great, that before noticing the plan for fancy dimity, it may be proper to allude to the dornock, the plan of which is represented by *fig. 6*.

The draught of dornock is precisely the same, in every respect, with that of striped dimity. It also consists of two sets of tweeling heddles, whether three, four, or five leaves, are used for each set. The left hand set of treddles is also corded exactly in the same way, as will appear by comparing them. But, as the dimity is a continued stripe from the beginning to the end of the web, only five treddles are required to move ten leaves. The dornock, being checker-work, the weaver must possess the power of reversing this at pleasure. He therefore adds five more treddles, the cording of which is exactly the reverse of the former; that is to say, the back leaves in the former case having one leaf raised and four sunk, have, by working with these additional treddles, one leaf sunk and four leaves raised. The front leaves are in the same manner reversed, and the mounting is complete. So long as the weaver continues to work with either set, a stripe will be formed as in the dimity, but when he changes his feet from one set to the other, the whole effect is reversed, and the checkers formed. The dornock pattern upon the design paper, *Plate A*, may be thus explained: let every square of the design represent five threads upon either set of heddles, which are said by weavers to be once over the draught, supposing the tweel to be one of five leaves: draw three parallel lines, as under, to form two intervals, each representing one of the sets: the draught will then be as follows:—

The above is exactly so much of the pattern as is there laid down, to shew its appearance, but one whole range of the pattern is completed by the figure 1 nearest to the right hand upon the lower interval between the lines, and the remaining figures nearer to the right form the beginning of a second range or set. These are to be repeated in the same way across the whole warp. The lower interval represents the five front leaves; the upper interval the five back ones. The first figure 4 denotes that five threads are to be successively drawn upon the back leaves, and this operation repeated four times. The first figure 4 in the lower interval ex-

presses that the same is to be done upon the front leaves, and each figure, by its diagonal position, shews how often, and in what succession five threads are to be drawn upon the leaves, which the interval in which it is placed represents.

Dornocks of more extensive patterns are sometimes woven with 3, 4, 5, and even 6 sets of leaves; but after the leaves exceed 15 in number, they both occupy an inconvenient space, and are very unwieldy to work. For these reasons the diaper harness is in almost every instance preferred.

Fig. 7, represents the draught and cording of a fanciful species of dimity, which has been manufactured to great extent, although the prevalent taste for simplicity of pattern of the present day has rendered it less an object of demand than formerly. In this plan it will be observed, that the warp is not drawn directly from the back to the front leaf as in the former examples, but when it has arrived at either external leaf, the draught is reversed, and returns gradually to the other. The same draught is frequently used in tweeling, when it is wished that the diagonal lines should appear upon the cloth in a zig-zag direction. This plan exhibits the draught and cording, which will produce the pattern upon the design paper in *Plate A*. Were all the squares produced by the intersection of the lines denoting the leaves and treddles, where the raised dots are placed, filled the same as on the design, they would produce the effect of exactly one-fourth of that pattern. This is caused by the reversing of the draught, which gives the other side reversed as on the design, and when all the treddles, from 1 to 16, have been successively used in the working, one-half of the pattern will be complete. The weaver then goes again over his treddles in the reversed order of the numbers, from 17 to 30, when the other half of the pattern will be completed. From this similarity of the cording to the design, it is easy, when a design is given, to make out the draught and cording proper to work it, and when the cording is given to see its effect upon the design.

Fig. 8, represents the draught of the diaper mounting, and the cording of the front leaves, which are moved by treddles. The mounting, which raises the leaves of the harness, must be taken from the design paper, in a way similar to that used for the draw loom, and as described in that article. From the plan it will appear, that five threads are included in every mail of the harness, and that these are drawn in single threads through the front leaves, as described in the article DIAPER. The cording forms an exception to the general rule, that when one or more leaves are raised, all the rest must be sunk, for in this instance one leaf rises, one sinks, and three remain stationary. An additional mark, therefore, is used in this plan. The dots, as formerly, denote raising cords, the blanks sinking cords, and where the cord is to be totally omitted the cross marks \times are placed.

Fig. 9, is the draught and cording of a spot whose two sides are similar, but reversed. That upon the plan forms a diamond, similar to the one drawn upon the design paper, *Plate A*, but smaller in size. The draught here is reversed, as in the dimity plan, and the tredding is also to be reversed after arriving at 6, to complete the diamond. Like it too, the raising marks form one-fourth of the pattern. In weaving spots, they are commonly placed at intervals, with a portion of plain cloth between them, and are generally placed in alternate rows, the spots of one row being between those of the other. But as intervals of plain cloth must take place, both by the warp and woof, two leaves are added for that purpose. The front, or ground leaf, includes every second thread of the whole warp. The second, or plain leaf, that part which forms the intervals by the warp. The

remaining leaves form the spots; the first six being allotted to one row of spots, and the second six to the next row, where each spot is in the centre between the former. The reversed draught of the first is shewn entire, and is succeeded by twelve threads of plain. One-half of the draught of the next row is then given, which is to be completed exactly like the first, and succeeded by twelve threads more of plain, when one set of the pattern being finished, the same succession is to be repeated over the whole warp. As spots are formed by inserting woof of coarser dimensions than that which forms the fabric, every second thread only is allotted for the spotting. Those included in the front, or ground leaf, are therefore represented by lines, and the spot threads between them by marks in the intervals, as in the other plans.

The treddles necessary to work this foot are in number fourteen. Of these, the two in the centre, A, B, when pressed alternately, will produce plain cloth, for B raises the front leaf, which includes half of the warp, and sinks all the rest, while A exactly reverses the operation. The spot-treddles, on the left-hand, work the row contained in the first six spot-leaves, and those upon the right-hand the row contained in the second six. In working spots, one thread, or shot of spotting-woof, and two of plain, are successively inserted by means of two separate shuttles.

Disimilar spots are those whose sides are quite different from each other. The draught only of these is represented

by *fig. 10*. The cording depends entirely upon the figure, and may be supplied by the following simple rule: Having ruled the lines which represent the heddles, and crossed them by those representing the treddles, squares will be formed similar to those upon design-paper. The pattern being drawn upon design-paper, let the lines denoting the heddles represent the lines of the design, from top to bottom of the paper, and the treddle-lines the cross-lines. Place a raising-dot for every square which is coloured on the design, and the plan of cording will be correct. It is necessary, however, to remark, that when more than one square is included between the same parallel-lines, from top to bottom of the design, it is needless to transfer it more than once to the cording plan, for the treddle, being once marked, will repeat the operation as often as it is pressed, and, therefore, more than one treddle, for the same operation, would only load the loom with useless and cumbrous machinery. The plain leaves and additional leaves, for placing one row in the bosom of another, are quite the same in spots, whether similar or dissimilar. There is, indeed, a spot called a paper-spot, where all the warp is upon spot-leaves, except the intervals, and every second thread of woof is then coarse. It is undoubtedly superior in effect to the common spot; but, as it requires nearly twice the mounting, it is very expensive, and, therefore, little used. Some very beautiful specimens of it are occasionally imported from India.

Draw-loom

Draw-loom is the most complicated and extensive machine, in its operation, used in the weaving of ornamented cloth. There is no diversity of pattern, or figure, however extensive, which can be brought within the whole range of cloth of the largest dimensions, but may be produced by this useful, although expensive, machine. Draw-looms, in Britain, are used for three purposes, *viz.* for weaving damask, carpets, and the most extensive patterns of spotted muslins. The general principle of all these machines is pretty similar, but modifications in their construction take place, according to the particular purposes for which they are intended. When patterns become so extensive, that the number of heddles necessary for moving the warp in its numerous combinations, could neither be included within any moderate bounds, nor worked by any moderate power, it becomes necessary to have recourse to the draw-loom. Of all the draw-looms, that for weaving fine damask is the most extensive; some of those in common use containing upwards of 120 designs, of 10 spaces each, which renders them equal to 1200 leaves of the diaper harness, or 6000 of the leaves used for dornock, dimity, or common tweeling. The general principle of the draw-loom harness, and the mode by which the flushing is reversed, is in every respect the same with that of the diaper, the difference consisting solely in the superior extent of the former, and the method of mounting and working it. *Fig. 3. Plate XIV. Miscellany*, is a perspective view of the harness part of a draw-loom, and the apparatus for working it. The number of harness-cords of a draw-loom is so great, and they are of necessity so closely crowded together, that any representation of the whole, even if drawn upon a very large scale, must convey a very inadequate idea of their construction and operation. A few, therefore, only are represented at intervals to illustrate the way of constructing them, and this being once well understood, may be extended to any length that convenience will admit. The harness of the draw-loom is not confined by leaves, but every cord carrying a mail for the warp is kept stretched by a weight. The mails are the same as those of the diaper, *fig. 2. Plate XIV.* The weights attached to the harness are represented at L. A horizontal board, or frame C, is fixed across the loom, and is either perforated with a number of small holes, or divided by wires, or pins, to serve as guides to the cords of the harness passing through them. When the range, or extent of the design, has been ascertained, by counting on the paper the greatest number of squares contained in it from right to left, the harness must be made to correspond with this range. Let the

range be supposed to extend to 500 squares, and the whole breadth of the warp to contain 10,000 threads. If five threads are to be drawn through each mail, the number of mails composing the harness will be 2000, and four ranges of the pattern will include the whole breadth. The divisions in the board C, and the number of pulleys in the box, or case H, being adapted to this, the operator may proceed to put up his harness, which is done as follows: the 1st, 501st, 1001st, and 1501st harness twines, after being passed through their respective intervals in the board, or frame C, are to be knotted together at M. A cord being attached to these is carried over the first pulley in the case H, and is made fast to the piece of wood G, which is generally called the *table*. The 2d, 502d, 1002d, and 1502d, are connected in the same way, and the cord attached to them, passing over the second pulley, is fastened to the table as before. The same operation is successively repeated, until the whole 500 connections are completed. The cords at B, passing over the pulleys and fastened to the table, are called the *tail* of the harness. From each cord in the tail a vertical cord descends, and is made fast to a piece of wood K, which is lashed to a fixture in the floor. These cords, represented at D, are called *simples*. The draught of the warp through the mails of the harness is regularly progressive from right to left, as in common tweeling, and the draught, cording, and mounting of the front leaves are exactly the same as in diaper. A stout perpendicular cord is now stretched from the roof to the floor, and made fast at both ends. This cord is represented at I, and the loom is then ready to be adapted to work any pattern, of the range of 500 squares, or mails.

The next operation, therefore, is to apply a certain number of small cords, called *lashes*, and represented at E, so as to form the particular pattern required. This is called reading on the design, and from the complexity of the operation, and the necessity of its being accurately done, is performed by two persons. The first of these persons selects from the design paper the simples, to which lashes are to be successively applied; and it is the business of the second to apply those lashes according to the instructions which he receives from the first. To read or select the lashes in their proper rotation, it is proper to observe, that the whole range of squares, from right to left, between the extreme points of the pattern, is equal to the whole number of simples, and the whole range from top to bottom, to the number of operations which those simples are to undergo. The person who is to select, therefore, taking the design paper, begins

at the lowest square, and counting from the right hand, instructs the other to pass as many simples as there are blank squares upon the paper, to put lashes to as many as are coloured, again to pass the blanks, take the coloured squares, and so on until he has reached the left side of the pattern. When these lashes have been applied, which is done by passing each loosely round the simples which it is to work, they are knotted together, and attached to the cord I by a loop, so that they may slide up and down freely, both upon the cord and the simples. Proceeding to the second square from the bottom, the selection is made in the same way, and thus they continue until they have reached the top. The lashes being now in clusters upon the cord I, these clusters are connected at convenient distances from each other, by small cords represented at F, the first applied cluster being lowest upon the cord I.

The draw-loom being ready for work, the operators may begin to weave. Two persons are required to work the loom. One of these pulls down the first set of lashes, the whole being placed high upon the cord I, and by pulling them tight, draws the simples with which they are connected clear of all the rest. Then by grasping these simples firmly in his hand, and pulling them down, he tightens the tail cords at B, by making them diverge more from a straight line, and of course raises the mails which are attached to them by the harness twines at M. The weaver then works over his front, mounting, as in common tweeling, once, or oftener, if more squares than one, upon the design, are included between the same parallel straight lines from top to bottom. When a change of the harness becomes necessary, the connecting cord F pulls down the second cluster of lashes, upon which the same operation is performed as before. By these means, the simples, however numerous, (and in the case we have supposed they would amount to 500,) are selected from each other with the utmost accuracy and facility. The successive repetition of the same operation compleats the pattern, and then it is only necessary to push the lashes up again, and begin a new one.

When the mounting of the draw-loom is very extensive, it would be inconvenient to use only one case of pulleys; for the tail-cords and the frame of this case must be extended to very inconvenient dimensions. Besides this, when so many pulleys are employed, the tail-cords must deviate so much from the perpendicular line, that there would be much danger of throwing the cords off the pulleys, and setting the machine fast until each cord was replaced. Indeed, to prevent the danger of this, which materially impedes the operation, it is customary to place guides of wire under the pulleys, to confine the cords. But when the mounting is very extensive, two, and sometimes three, cases of pulleys are very generally used. These are placed parallel to each other, that represented at H being the middle one, and an equal number of tail cords are conducted over each. It is also usual to construct more than one set of simples, that which is to be used being lashed to the floor, while the others are loose and hung near the roof, until it becomes necessary to use them in their turns. This, indeed, is very useful in working bordered table-cloths, where the whole is frequently the continuation of one design, extending sometimes three yards, or more, in breadth, and five or six yards in length.

In an age like the present, when simplification of process and saving of labour have become objects of such general attention, it is not wonderful that plans, which have these for their object, should have been adapted to the draw-loom as well as to other machinery. One of these, lately introduced at Dunfermline, has been pretty generally adopted,

and appears, upon the whole, to have given very considerable satisfaction. Whether properly or not, it is there known by the name of the patent draw-loom.

The object of the patent draw-loom is, to enable the weaver to change his harness, as well as to perform the other necessary operations of weaving, and consequently to supersede the necessity of employing a second person at the loom. In this loom the tail of the harness, instead of having its direction changed, by passing over pulleys, and being carried to one side, rises perpendicularly, and is made fast to the roof. The simples are brought in a horizontal direction to the front of the loom, over the weaver's head. The direction of the simples is very similar to that of the tail cords of the diaper-loom, *fig. 1*. The lashes hang down perpendicularly, so that the weaver may pull them with his hand. Upon the tail are knots, placed at equal heights from the floor, and in front of these knots is an instrument very much resembling a coarse comb, or the teeth of a garden rake. This instrument moves upon a fulcrum, from which a lever extends over the weaver's head, by depressing the end of which he can raise the teeth at pleasure. The simples being pulled, the tail is drawn forward, and the knots engaged between the teeth of the comb. The lever being then pulled down, and secured by a cord and handle, as in the diaper-loom; the teeth rise, and carrying the knots along with them, raise the harness. When a change is required, the teeth are let down, the knots relieved, a second set pulled in, and the operation proceeds as before.

This plan has come into very general use, and seems to meet with much approbation, for those kinds of damask where the pattern is not very extensive. In the others, there is still a diversity of opinion respecting the comparative merits of the old and new plans, which, as the invention is recent, will probably be only decided by experience.

The draw-loom is also applied, in most instances, to the manufacture of carpets. Carpets are not tweeled like diaper or damask, but consist of plain or alternate weaving. A carpet consists of two webs of cloth, woven separately and independently of each other, but being woven at the same time, particular parts of them are taken through each other, so that any part of each web is sometimes above, and sometimes below the other. From this it arises that when a carpet is turned upside down, the pattern remains the same, but the colours are reversed, that which formed the ground being now the pattern, and *vice versa*.

The front mounting of a carpet draw-loom consists of four leaves, two of which raise the web which forms the ground, and the other two that which forms the figure. One shot of the woof is inserted into each web alternately. The eyes of the front mounting are long, like those of the diaper and damask, to allow the harness to rise freely. As carpets are woven generally of coarse dyed woollen yarn, and do not contain much warp, it is unnecessary, except in very complicated patterns, to use simples. The lashes, therefore, hang perpendicularly from the tail, and at the end of each set there is a small handle, or as it is called, a *bob*. These pass through a long horizontal board, perforated with holes to preserve their regularity, and are arranged in pairs, one bob raising the harness of the pattern-web, and the other that of the ground-web. To adapt the figure upon the design to the application of the lashes, the instructions for the pattern-web are the same as in the damask; those for the ground-web the same exactly reversed. In the latter, therefore, the blanks upon the design are to be taken, and the coloured squares passed. In this consists the whole difference.

The harness of the spot draw-loom is exactly the same as

the damask, excepting that the yarn of the warp being much finer, the mails are not used, but short eyes of twine substituted in their places. In the front mounting, also, the end is attained by means which, although in effect the same, are better adapted to the particular nature of the work. Four leaves of heddles are used; but they are mounted, so that two leaves will either go together up or down, or in opposite directions. The heddles are constructed like those for weaving plain cloth, and every thread is drawn through two heddles, being taken through the upper cleft or link of the one, and through the under link of the other. When the two leaves move in the same direction, the threads of warp are confined as in the clasp of a common heddle; but when they move in a contrary direction, they present all the facility of the long eye in allowing the harness to rise without interruption.

As the time, labour, and materials, necessary to mount a draw-loom involve a very considerable expence, before any

productive return can be attained, it is of the utmost importance that the quality of the materials should be good, and that every part should be square, level, and equally stretched. Draw-looms will only gradually remunerate those who expend money or labour in fitting them up; and the better they are executed, the quicker and more certain will be the return. A trifling additional trouble or expence to attain those ends will therefore always be found consistent with the soundest judgment, and truest economy.

Draw-Net, a kind of net for taking the larger sort of wild fowl, which ought to be made of the best packthread, with wide meshes: they should be about two fathoms deep, and six long, verged on each side with a very strong cord, and stretched at each end on long poles.

It should be spread smooth and flat upon the ground, and strewed over with sedge, grass, or the like, to hide it from the fowl; and the sportsman is to place himself in some shelter of grass, fern, or some such thing.

Dredging-machine

DREDGING-MACHINE, in *Mechanics*, an engine used to take up mud, or gravel, from the bottom of rivers, canals, docks, harbours, &c. while they remain full of water.

The common method of dredging is performed by men in a barge: the gravel, or ballast, is taken up in a leather bag, the mouth of which is extended by an iron hoop, attached to a light pole, of a sufficient length to reach the bottom: in the small way, two men are employed to work each pole. The barge being moored, one of the men takes his station at the stern, with the pole and bag in his hand, the other stands in the head, having hold of a rope, tied fast to the hoop of the leather bag. The man at the stern now puts the pole and bag down, over the barge's side, to the bottom, in an inclined position. The hoop being farthest from the man in the head of the barge, and having a rope, one end of which is fast to the gunwale of the barge, he passes it twice, or thrice, round the pole, and then holds it tight: the man in the head now pulls the rope, fastened to the hoop, and draws the hoop and bag along the ground, the other allowing the pole to slip through the rope as it approaches the vertical position, at the same time causing such a friction, that the hoop digs into the ground, the leather bag receiving whatever passes through the hoop: both men now assist in getting a bag into the barge, and delivering its contents.

When the bag is large, several men are employed; and, to increase the effect, a windlass, with wheel-work, is used to draw the hoop along the ground. It is in this manner the convicts at Woolwich upon the Thames perform the ballast heaving, or dredging, which they are condemned to labour at as a punishment.

In large rivers, which require much dredging to keep the channel at the proper depth, the above method of manual labour becomes so expensive, that a large machine, worked by horses or a steam engine, is usually employed; two such machines worked by a steam engine have been some time in use in the river Thames, one of them is represented in *Plate III. Hydraulics*, which contains an elevation and plan of the engine.

It is erected in the hulk of a disabled ship. *A A*, *fig. 1*, is a frame of timber bolted to the starboard gunwale, to support a large horizontal beam, *B B*, *fig. 2*; another similar frame is fixed up in the middle of the ship at *D*, *fig. 2*, and the end of the beam is sustained by an upright post bolted to the opposite gunwale, the starboard end of the beam projects over the vessel's side, and has an iron bracket *S* fastened to it, to support one of the bearings for the long frame *E E*, composed of four timbers bolted together: the other end of the frame is suspended by pulleys *a, a*; from a beam *F* fixed across the stern, the upper ends of the outside beams of the frame *E E* have each a stout iron bolted to them, which are perforated with two large holes to receive two short cast iron tubes, one fastened to the iron bracket *S* at the end of the beam *B*, and the other to a cross beam of the frame *A*; these tubes act as the pivots of the frame *E*, upon which it can be raised or lowered by the pulleys *a, a*: they also contain bearings for an iron axis, on which a wheel or trundle *O* is fixed, containing four rounds. Another similar trundle *P* is placed at the bottom of the frame *E E*, and two endless chains *k, k*, pass round both, as is seen in the plan. Between every other link of the two chains, a bucket of plate iron *b b b* is fastened, and as the chain runs round, the buckets bring up the soil; a number of cast iron rollers *d, d*, are placed between the beams of the frame to support the chain and buckets as they roll up. Four rollers *e, e*, are also placed on each of the outside beams, to keep the chains in their places on the

frame, that they may not get off to one side. The motion is conveyed to the chains by means of a cast iron wheel at *G* in the plan, wedged on the end of the axis of the upper trundle *O*. The wheel is cast hollow, like a very short cylinder, and has several screws tapped through its rim, pointing to the centre, and pressing upon the circumference of another wheel inclosed within the hollow of the first, that it may slip round in the other where any power greater than the friction of the screw is applied; the internal wheel is wedged on the same shaft with a large cog-wheel *f* turned by the small cog-wheel *g* on the axis of the steam-engine. The steam-engine is one of that kind called high pressure, working by the expansive force of the steam only, without condensation; *b* is the boiler containing the fire place and cylinder within it; *i* is one of the connecting rods, and *l* the fly wheel on the other end of the same shaft as the wheel *g*. For a more particular description of the engine, see *STEAM ENGINE*.

The pulleys *a*, which suspend the chain frame, are reeved with an iron chain, the tackle fall of which passes down through the ship's deck, and is coiled on a roller *m* in the plan, and represented by a circle in the elevation: on the end of the roller is a cog-wheel *p*, turned by the engine wheel *g*: the bearing of this wheel is fixed upon a lever, one end of which comes near that part of the steam-engine, where the cock which regulates the velocity of the engine, is placed; so that one man can command both lever and cock, and by depressing that end of the lever, cause the wheel *p* to gear with *g*, and consequently be turned thereby, and wind up the chain of the pulleys; *g* is a strong curved iron bar bolted to the vessel's side and gunwale, passing through an eye bolted to the frame *E*, to keep the frame to the vessel's side, that the tide or other accident may not carry it away.

A large hopper or trough is suspended beneath the wheel *o*, by ropes from the beam *B*, into which the buckets *b, b, b*, empty the ballast they bring from the bottom; the hopper conveys it into a barge brought beneath it: this hopper is not shewn in the plate, as it would tend to confuse parts already not very distinct. The motion of the whole machine is regulated by one man. The vessel being moored fast, the engine is started, and turns the chain of buckets, the engine tender now puts his foot upon a lever, disengages the wheel *p* from *g*, and by another takes off a gripe which embraced the roller *m*. This allows the end *E* of the frame to descend, until the buckets on the lower half of the chain drag on the ground, as shewn in *fig. 1*, when he stops the further descent by the gripe, the buckets are filled in succession at the lower end of the frame, and brought up to the top, where they deliver their contents into the hopper before-mentioned: as they take away the ballast from the bottom, the engine tender lets the frame *E* down lower by means of the gripe lever, and keeps it at such a height that the buckets come up nearly full; if at any time the buckets get such deep hold as to endanger the breaking of the chain or stopping the engine, the coupling-box at *G* before-described, suffers the steam-engine to turn without moving the chain of buckets, and the engine tender pressing his foot upon the lever which brings the wheel *p* to gear with *g*, causes the roller *n* to be turned by the engine, and raise up the frame *E*, until the buckets take into the ground the proper depth, that the friction of the coupling-box at *G* will turn the chain without slipping in any considerable degree.

The steam engine is of six horses power, and is so expeditious, that it loads a small barge with ballast in an hour and a half.

Drill

DRILL, in *Mechanics*, a tool made of hardened steel, used to bore holes in metal; they are of various forms, the most useful of which are shewn in *Plate XXIV. Mechanics*.

Fig. 1. is the common lathe or crank-drill, having an angular point, and two cutting edges, *aa*, which are only adapted to be turned one way; it is therefore adapted for drilling any work in the lathe, or by the crank, which is formed of iron, having a socket at the lower end to receive the drill; the upper end is pointed, and is pressed upon by a lever loaded with a weight. The workman turns the drill round by means of the elbow of the crank, and the weight and lever keep it to its work.

Fig. 2. is the ordinary drill, having the cutting edge, as shewn in the side view *B*, made so as to cut either way; it is used with the crank, but chiefly with the bow.

Fig. 3. is like the former, except that it has a round edge; it is used for drilling steel and hardened iron, where, from the hardness of the work, a point might fail.

Fig. 4. is a drill, where the cutting edge (*ab* in *fig. D.*) crosses the point. The cutting side of the edge at *a* is toward *fig. A*; and at the other side of the centre; viz. at *b*, it is toward *D*; the edge is therefore somewhat like a screw, and leads itself into the work; for which reason it is good for drilling lead, copper, and other metals, which are tough without being very hard.

Fig. 5. is called a pin drill, and is used for drilling very large holes. A small drill, like *figs. 1* or *2*, is first used, and the hole, thus made, just fits the pin *aa*, and keeps the drill steady while it is turned round. It has two cutting edges, *b* and *d*; in *b* the face is towards the eye of the spectator, and *d* represents the back of the edge; the edge is a little hollowed out above at *b* in the edge view, to make a thinner and sharper edge.

Fig. 6. is a countersunk drill, which is used to make holes to receive the heads of screws; a hole is first drilled by the common drill, which is the size of the body of the screw, and the pin *a* just fits it, the cutting part *db* is the size of the head of the screw, *ee* is a shoulder, which prevents the drill cutting any further than intended.

Drills for small work are turned by means of a small pulley fitted on them; the string of an elastic bow is passed round it. The piece of metal to be drilled, is fixed in a vice, and the point of the drill applied to it; the other end is placed in a hole in a piece of metal held against the breast of the operator; by drawing the bow backwards and forwards, a rapid motion is given to the drill, though it is not always in the same direction; therefore, the drill should be shaped like *fig. 1*.

To avoid the trouble of making a great number of pulleys, workmen frequently use drill stocks, which will fit any size drill with the same pulley.

Fig. 7. is one of these where the drill *A* is formed of a round piece of steel wire, and pushed into a round hole, a little taper in the end of the stock *B*; *a, a*, are notches to push out the end of the drill in case it breaks in the stock. Sometimes the hole in the stock is square, for unless the work is very light, the round ones are apt to slip.

Fig. 8. is a neat contrivance to obviate this difficulty, communicated to us by Mr. T. Gill. The hole in the end of the stock is cylindrical, and the wire of the drill has one side filed flat, a small pin is put through one side of the hole, as shewn by the small round circle, and the flat side of the wire applies itself to it; by this means, the drill cannot turn round, and always fits tight in its socket.

Fig. 9. is a steel bow for giving motion to a drill as before explained. *A* is the steel part formed into a hook at the end, to hold the catgut *B*. At the other end, the steel is enlarged to receive a thumb-nut *D*, on which the catgut is wound, *d* is a small ratchet wheel fastened to the nut *D*, and fitted with a click to prevent its turning back. The use of the ratchet is to draw up the catgut, so that it may fit any size pulley on the drill.

In large manufactories where much large drilling is to be performed, it is done by machinery usually turned by a steam engine.

Figs. 10. and *11.* are elevations, at right angles to each other, of a machine of this kind. *A*, *fig. 10.* is a shaft, bringing the power to the machine, *B* a bevelled wheel fixed thereon, giving a rotative motion to another, *D*, on a vertical axis, *E*, turning in bearings *d, d*; this axis is perforated with a square hole throughout to receive a square iron bar *e*, at the lower end whereof the drill *f* is fixed. The work to be drilled is placed on a stool *F* upon the floor, that it may be readily moved about; in the drawing it is supposed to be a cylinder lid; the drill is pressed down upon the work by a lever *G*, the fulcrum of which is *g*, at the other end of the lever is jointed an iron rod *h*, having a rack *k* cut in the lower end; this rack is moved by a pinion on the axis of a toothed wheel *l* turned by another pinion, on whose spindle is the winch *m*; the upper end of the iron bar *e* is pointed, and works in a hole in the lever; a collar *n* is put over the lever and keyed upon the bar *e*, so that the lever will lift up the drill as well as force it down upon the work.

The operation of the machine is very simple; the drill being constantly in motion, the workman turns the winch *m*, and raises the drill above the work, he then adjusts the work by moving the stool *F* and laying the piece upon wedges to the proper place, and by turning the winch *m* back, he brings the drill down upon the work with any degree of force he pleases. The drill must be supplied with cold water, otherwise the friction would heat and soften it. The drill is fitted into its socket by a square, the socket is open above the drill, as shewn in *fig. 11*, that it may be driven out to change it for another.

Drills are hardened by heating them in the fire to a red heat, and plunging them in cold water. They are then rubbed bright in some part by a stone, file, &c. and again heated in the fire, till the bright part assumes a light straw colour, when they are cooled in water. Small drills are heated in the candle by a blow pipe, and cooled in the tallow.

It is a very well known fact, that a drill made of iron has frequently not only a polarity, but so strong an attractive virtue of the magnetic kind, that it will suspend a common

needle from its point. It is usually supposed that a drill acquires this polarity by boring iron. But it is not only by boring of iron that this power is obtained, but in the very making. As soon as one of them is finished and hardened, its point becomes a north pole before it has ever been worked either in iron or any other materials, so that of the great numbers of these instruments found in a shop, endowed with this power, it is to be supposed that more of them owe it to their original make than to any after-use. All pieces of wrought iron, which in shape resemble drills, that is, which are of a long and slender form, will not only have this polarity, but they will change it on being placed for some time in an inverted posture, and that which was the opposite to the north pole, by standing downwards will be the north pole. This has been an old observation, but on a fair experiment it does not prove to be true in all things without exception, though it be so in most particulars. The larger pieces of iron seem to be most easily influenced in their polarity, by changing their position; but the small ones will sometimes be found to have fixed poles, which no change of posture will alter. *Phil. Trans. N° 246. See MAGNET.*

Ductility

DUCTILITY, (from the Latin *duSile*,) means the property, or the capability, of becoming extended. The word *expansibility* has been more commonly applied to denote the enlargement of such bodies as consist, or seem to consist, of separate parts, like the effluvia of odoriferous substances, colouring pigments, cotton, wool, &c. But the word *ductility*, denotes the enlargement of the dimensions of solids, without losing their continuity and consistence. This property almost exclusively belongs to metallic bodies; for it can hardly be discerned in a few other bodies.

The methods of extending metallic bodies may be reduced to three: *viz.* by the strokes of a hammer, by the more equable pressure of flattening or rolling mills, and by drawing the metal through small holes in a steel plate, as is practised in wire-drawing. And since the first of those methods has been more generally and more usually practised; therefore the words malleability and ductility have been indiscriminately used to express the same thing.

To these impressions certain metallic bodies yield much more readily than others, and some there are which will not yield at all; so that, when pressed or hammered, they will rather break into fragments than expand.

Previous to the statement of the various degrees of ductility, it will be necessary to say a few words with respect to the nature of dilatability itself, in order to prevent a wrong notion which unexperienced persons are liable to adopt. When a piece of metal, in consequence of its ductility, is said to be extended; the meaning is not that the bulk of the metal is enlarged; but that one or two of its dimensions, (*viz.* the length, the breadth, or the thickness,) is enlarged, whilst one or both the others are diminished. For instance, a cubic inch of gold is one inch long, one inch broad, and one inch thick; and the product of these three dimensions, which gives the solidity, is one inch. Now if, by hammering, you extend the length of it, so as to make it two inches long, the breadth remaining the same, the thickness will be reduced to half an inch; and the product of these three dimensions; *viz.* two inches, one inch, and half an inch, is

equal to one inch, as before; which shews that the solid contents remain the same.

It must, however, be observed, that, strictly speaking, the bulk of a piece of metal is a little contracted by the hammering or pressing; so that a sort of concentration and hardening take place at the same time. In fact, the specific gravity of a piece of ductile metal is greater after the hammering or pressing than before. Both this additional hardness and increased specific gravity are removed by heating the piece of metal to a certain degree.

Though we have mentioned the drawing through holes as one of the methods of extending metallic bodies; yet a necessary distinction must be pointed out with respect to this operation.—In the present state of philosophy, *ductility* is distinguished from *tenacity*. The meaning of the former has already been explained; but the tenacity is measured by the resistance which a wire of the metal opposes, without breaking, to the action of a certain force which draws it at one extremity, while the other extremity is fixed. Now it is upon this tenacity that the drawing of metals through holes depends. And, in fact, certain metals which shew under the hammer, or under the flattening mill, a much greater degree of ductility than others, are, at the same time, less capable of being drawn into fine wire, and *vice versa*; as will appear from the following lists.

Of all the metallic bodies some are ductile, whilst others are not, and this difference caused them to be distinguished into two classes; calling the former metals, and the latter semi-metals, or imperfect metals; but the limits of these classes being very indefinite, little regard is now paid to this nominal distinction.

Ductile Metallic Bodies arranged in the Order of their Ductility.

Gold,
Platina,
Silver,
Copper,

Iron,
Tin,
Lead.

Metallic Bodies arranged in the Order of their Tenacity.

Gold,		Silver,
Iron,		Tin,
Copper,		Lead.
Platina,		

For farther particulars respecting the tenacity of metals, see the articles *TENACITY*, and *WIRE Drawing*.

The ductility of gold exceeds that of every other metallic body, and since its value and its beauty have at all times encouraged the industry of workmen, no pains have been spared in endeavouring to expand the surface of it to the utmost limit of practicability; and a single grain weight of gold is now commonly extended into a surface equal to 50 square inches and upwards. Mr. Magellan says, that the finest gold leaf is extended by hammering between new skins, and that each troy ounce of pure gold must be alloyed with three grains of copper, otherwise it would be too soft to pass over the irregularities of the skins. When extended to the utmost, 2000 leaves of such gold, each containing a surface of 10.89 square inches, weigh less than 384 grains; so that each grain weight of the metal will produce about 57 square inches of gold leaf; and it is easily determined by calculation, that the thickness of such gold leaf is about $\frac{1}{21500}$ th of an inch. However, this is a considerable thickness, in comparison of that of gold spun on silk in our gold thread.

To conceive this prodigious ductility, it is necessary to have some idea of the manner, wherein the wire-drawers proceed. The wire and thread we commonly call gold thread, &c. which is only silver wire gilt, or covered over with gold, is drawn from a large ingot of silver, usually about thirty pounds weight. This they round into a cylinder, or roll, about an inch and a half in diameter, and twenty-two inches long, and cover it with the leaves prepared by the gold-beater, laying one over another, till the cover is a good deal thicker than that in our ordinary gilding; and yet, even then, it is very thin; as will be easily conceived from the quantity of gold that goes to gild the thirty pounds of silver: two ounces ordinarily do the business; and, frequently, little more than one. In effect, the full thickness of the gold on the ingot rarely exceeds $\frac{1}{200}$ th, or $\frac{1}{300}$ th part: and sometimes not $\frac{1}{2000}$ th part of an inch.

But this thin coat of gold must be yet vastly thinner: the ingot is successively drawn through the holes of several irons, each smaller than the other, till it be as fine, or finer, than a hair. Every new hole lessens its diameter; but it gains in length what it loses in thickness; and, of consequence, increases in surface: yet the gold still covers it; it follows the silver in all its extension, and never leaves the minutest part bare, not even to the microscope. Yet, how inconceivably must it be attenuated while the ingot is drawn into a thread, whose diameter is 9000 times less than that of the ingot!

M. Reaumur, by exact weighing, and rigorous calculation found, that one ounce of the thread was 3232 feet long; and the whole ingot 116,3525 feet, Paris measure, or 96 French leagues; equal to 126,4400 English feet, or 240 miles English; an extent which far surpasses what Fa. Merfenne, Furetiere, Dr. Halley, &c. ever dreamt of.

Merfenne says, that half an ounce of the thread is 100 toises, or fathoms long; on which footing, an ounce would only be 1200 feet; whereas, M. Reaumur finds it 3232. Dr. Halley makes six feet of the wire one grain in weight, and one grain of the gold ninety-eight yards; and, consequently, the ten thousandth part of a grain, above one third of an inch. The diameter of the wire he found one 186th part of an inch; and the thickness of the gold one 154,500th

part of an inch. But this, too, comes short of M. Reaumur; for, on this principle, the ounce of wire would only be 2680 feet.

But the ingot is not yet extended to its full length. The greatest part of our gold thread is spun, or wound on silk, and, before they spin it, they flat it by passing it between two rolls, or wheels of exceedingly well polished steel; which wheels, in flattening it, lengthen it by above one seventh. So that our 240 miles are now got to 274. The breadth, now, of these laminæ, or plates, M. Reaumur finds, is only one 8th of a line, or one 96th of an inch; and their thickness, one 3072d. The ounce of gold, then, is here extended to a surface of 1190 square feet; whereas, the utmost the gold beaters can do, we have observed, is to extend it to 146 square feet. But the gold, thus exceedingly extended, how thin must it be! From M. Reaumur's calculus, it is found to be one 175,000th of a line, or one 2,100,000th of an inch: which is scarce one 13th of the thickness of Dr. Halley's gold. But he adds, that this supposes the thickness of the gold every where equal, which is no ways probable; for in beating the gold-leaves, whatever care they can bestow, it is impossible to extend them equally. This we easily find, by the greater opacity of some parts than others; for where the leaf is thickest, it will gild the wire the thickest.

M. Reaumur, computing what the thickness of the gold must be where thinnest, finds it only the 3,150,000th part of an inch. But what is the one 3,150,000th part of an inch? Yet this is not the utmost ductility of gold: for instead of two ounces of gold to the ingot, which we have here computed upon, a single one might have been used; and, then, the thickness of the gold, in the thinnest places, would only be the 6300,000th part of an inch.

And yet, as thin as the plates are, they might be made twice as thin, yet still be gilt; by only pressing them more between the flatter's wheels, they are extended to double the breadth, and proportionably in length. So that their thickness, at last, will be reduced to one thirteenth, or fourteenth millionth part of an inch.

Yet, with this amazing thinness of the gold, it is still a perfect cover for the silver: the best eye, or even the best microscope, cannot discover the least chasm, or discontinuity. There is not an aperture to admit alcohol of wine, the subtlest fluid in nature, or even light itself, unless it be owing to cracks occasioned by repeated strokes of the hammer. Add, that if a piece of this gold-thread, or gold-plate, be laid to dissolve in aquafortis, the silver will be all excavated, or eat out, and the gold left entire, in little tubules.

It should be observed, that gold, when it has been struck for some time by a hammer, or violently compressed, as by gold wire-drawers, becomes more hard, elastic, and stiff, and less ductile, so that it is apt to be cracked or torn: the same thing also happens to the other metals by percussion and compression. But ductility and tractability may be restored to metals in that state, by annealing them, or making them red-hot. Gold seems to be more affected by percussion and annealing, than other metals.

Platina, silver, and copper, may, likewise, be expanded into leaves, but not nearly so thin as those of gold.

With respect to the arrangement of iron and tin in the first of the above-stated lists, we are not quite determined as to which of them the preference may be due.

Zinc has the remarkable property of being malleable, or ductile, not in the usual temperature of the atmosphere, but in a higher temperature. When heated to between 210° and 390° of Fahrenheit's thermometer, zinc is perfectly malleable, and may be stretched into wires, or into pretty thin plates. And when so treated, it will afterwards remain mal-

leable. Some metallic substances do not suffer the strokes of a hammer nearly so well as the more uniform pressure of the flattening mill; and this is peculiarly the case with zinc.

It is not with zinc alone, but with all other ductile metals, that their ductility is greater in a certain temperature, which generally exceeds that of the atmosphere; thus iron in a red heat is incomparably more ductile than at a lower temperature. Heat, in short, tends to soften the metal; or, which amounts to the same thing, to increase its ductility; and as hammering or rolling hardens the metal at the same time that it extends it, the workmen, in the course of their operation, find it necessary to soften the metal by the application of heat, in order to render it capable of farther extension. This heating or softening is, in some cases, repeated several times before the work is quite finished.

The alloys of two or more metallic bodies are less ductile, than the pure metals themselves; yet such alloys are highly useful in a variety of cases, and the pure metals are often alloyed for no other purpose than for diminishing their softness and ductility. In the coinage of most countries the noble metals are generally alloyed with a little copper, which increases their hardness and elasticity.

The most extensively useful alloy is that of copper and zinc, which forms *brass*.—Its colour, its ductility, and its not being easily oxydated, have rendered it peculiarly useful for a variety of purposes, and especially in watch-work, where no other metallic substance has been found nearly so useful.

Brass, when properly made, is ductile and tenacious to a considerable degree. It will extend pretty well under the hammer, and it may be easily drawn into very fine wire. A slight degree of heat will, in some measure, increase its ductility; but when heated to about 300°, or upwards, then the strokes of the hammer will reduce it to powder. It is a sort of brass (but the precise proportion of the ingredients is kept secret,) that is expanded into leaves like gold; and is commonly sold under the name of *Dutch gold*.

Though tin is more ductile than zinc; yet the alloy of copper and tin is, upon the whole, less ductile than that of copper and zinc. Paerner says, that much copper and little tin form a malleable compound, as well as much tin and little copper; but that when the two metals are alloyed from eight to ten parts of copper to one of tin, then the alloys are brittle and untractable.

The alloy of lead and antimony forms the metal which is used for printer's types, and its ductility may be varied by varying the proportion of antimony. According to Gmelin, one part of antimony and 12 parts of lead, form a hard alloy, but capable of being beat into sheets. One part of antimony and eight parts of lead, form a compound harder and more fusible than lead, but malleable; and such is also the case

with one part of antimony and three of lead; but with a smaller proportion of lead the compound is too hard to bear the strokes of the hammer.

An alloy of zinc and lead has, on account of its brilliancy and hardness, been recommended for the construction of economical and other articles. When a great deal of zinc is alloyed with lead, the compound is harder than lead, but very malleable. See METALS, GOLD, &c.

DUCTILITY of Glass. We all know, that, when well penetrated with the heat of the fire, the workman can figure and manage glass like soft wax; but what is most remarkable, it might be drawn, or spun out into threads, exceedingly fine and long.

Our ordinary spinners do not form their threads of silk, flax, or the like, with half the ease and expedition, as the glass spinners do threads of this brittle matter. We have some of them used in plumes for children's heads, and divers other works, much finer than any hair, and which bend and wave like it with every wind.

Nothing is more simple and easy than the method of making them: there are two workmen employed; the first holds one end of a piece of glass over the flame of a lamp; and, when the heat has softened it, a second operator applies a glass hook to the metal thus in fusion; and, withdrawing the hook again, it brings with it a thread of glass, which still adheres to the mass: then, sitting his hook on the circumference of a wheel about two feet and a half in diameter, he turns the wheel as fast as he pleases; which, drawing out the thread, winds it on its rim; till, after a certain number of revolutions, it is covered with a skin of glass thread.

The mass in fusion over the lamp diminishes insensibly; being wound, as it were, like a pelatoon, or clue of silk, upon the wheel; and the parts, as they recede from the flame, cooling, become more coherent to those next to them; and this by degrees: the parts nearest the fire are always the best coherent, and, of consequence, must give way to the effort the rest make to draw them towards the wheel.

The circumference of these threads is usually a flat oval, being three or four times as broad as thick: some of them seem scarce bigger than the thread of a silk-worm, and are surprisingly flexible. If the two ends of such thread be knotted together, they may be drawn and bent, till the aperture, or space in the middle of the knot, doth not exceed one 4th of a line, or one 48th of an inch diameter.

Hence M. Reaumur advances, that the flexibility of glass increases in proportion to the fineness of the threads; and that, probably, had we but the art of drawing threads as fine as a spider's web, we might weave stuffs and cloths hereof for wear. Accordingly, he made some experiments this way; and found he could make threads fine enough, as fine in his judgment, as any spider's web: but he could never make them long enough to do any thing with them.

Durham

DURHAM, a county in the northern part of England, bounded to the east by the German ocean, to the north by Northumberland, from which it is separated by the rivers Tyne and Derwent, on the west by the counties of Cumberland and Westmoreland, and on the south by Yorkshire. The area thus enclosed forms a triangular figure, and measures about 36 miles in its greatest extent from north to south, by nearly 45 miles in an opposite direction. Its su-

This part of England was anciently inhabited by the *Brigantes*, a class of Britons, distinguished by Tacitus as being powerful, brave, and numerous; but who were subdued by the Romans. The latter included Durham within the division of *Maxima Cæsariensis*; and the Saxons made it part of the kingdom of Northumbria. In the year 685, Egfrid, king of this district, granted all the lands between "the rivers Wear and Tyne" to St. Cuthbert, the apostle of the north. From this time the county was invested with great privileges, and has been generally termed the *Bishopric*, and *County palatine*. Edward I., however, seized the power from the bishop, and transferred the liberties of the fee to the crown. These were afterwards restored in part; and were augmented or enlarged by different monarchs, till queen Mary re-established them. The bishops of Durham, from time immemorial, have exercised peculiar immunities and power; consisting of all manner of royal jurisdiction, both civil and military, by land and sea. For the exercise of which they had their proper courts of chancery, exchequer, and court of pleas, as well of the crown as of the county. The nature and peculiarity of all these cannot be properly described in this place, but may be found fully explained in Hutchinson's History of Durham, 3 vols. 4to. and Gough's edition of Camden's Britannia, vol. iii. p. 109, &c.

The general aspect of Durham is hilly and mountainous, particularly towards the western angle, which is a bleak, barren, and naked region, crossed by a lofty ridge called the English Apennines. Several different streams issue from the eastern side of these mountains. On the eastern side, and near the centre of the county, are some fine and fertile vallies, through which various brooks and rivers flow to the sea. Nearly one-third of the land is held by ecclesiastical tenure, under leases for lives, or for 21 years. The cattle of Durham are in great repute, as to shape, weight, produce of milk, &c. The sheep are mostly large, and covered with long wool.

The waste or uncultivated lands of this county are of considerable extent; occupying, according to Mr. Granger, superficial area includes about 610,000 acres. This space is divided into four wards, all of which derive their names from places of little importance, viz. Chester, Darlington, Easington, and Stockton; besides which there are two other districts, called Northamshire and Islandshire. The county is divided, according to some authors, into 113 parishes, while others say 120, including one city and ten market towns. According to the last report to parliament, this district contained 27,195 houses, and 160,361 inhabitants, of whom 74,770 were males, and 85,591 were females. Four members are returned to parliament; two for the county and two for the city.

nearly 130,000 acres. According to Sir William Appleby, in a communication to the author of the Agricultural Report, "Durham, taking its small dimensions into consideration, is not to be equalled by any other county in Great Britain, except Middlesex, for its numerous and important coal, lead, and iron mines; its large cast-metal foundries, and iron manufactories, potteries, glass-houses, copperas works, coal, tar, and salt works, quarries of marble, fire and free-stone; lime, brick, and tile-kilns; grind-stone and mill-stone; linen and woollen manufactories; trade, agriculture, and population." Granger's general View of the Agriculture of the County of Durham, 4to.

Towards the east and north-east parts of Durham are several extensive coal-mines. The seams or strata, now worked, are five in number, which extend horizontally for many miles, and are from 20 to 100 fathoms beneath the surface. Each stratum is from three to about eight feet in thickness. Below these are several other seams of coal. Some steam-engines have been erected, to raise the coal to the surface, and for the purpose of pumping the water out of the mines. In the great sea-coal collieries, several horses are constantly kept under ground, to draw the coals to the mouths of the pits.

In the vicinity of Walsingham, a firm black spotted limestone or marble is procured, and is much used for hearths, chimney-pieces, &c. The same neighbourhood also abounds with stone, much used in making mill-stones. Many quarries of excellent slate have been opened in different parts of the county; and Gateshead-fell is particularly famous for producing what are vulgarly termed Newcastle grind-stones, from being mostly shipped off at that port. Fire-stone, in high estimation for making ovens, furnaces, &c. is obtained in various parts of the county; and large quantities are annually exported. Several lead-mines are worked in Teesdale and Wear-dale. Some extensive works for manufacturing salt from sea-water have been long established at South Shields; but these have been much neglected, in consequence of a singular salt spring having been discovered at Birtley. The water rises at the depth of 70 fathoms, and has produced 20,000 gallons per day for some years past. The water is found to be four times stronger than any sea-water.

The manufactures of Durham are numerous and important, and are distributed over various parts of the county. At Chester-le-Street is a very extensive foundry for cannon; and another at Washington. At Swalwell and at Winlaton are some very large iron-works; and at Lumley is a manufactory for converting scrap-iron into engine-boiler-plates, and cast metal into malleable iron. At Shortley-bridge, Derwent-Coal, and Blackhall-Mills, are manufactories of steel for sword-blades. Tammies, carpets, and waistcoat-pieces, are manufactured at Durham; tammies and buckabacks are also made at Darlington; cottons are manufactured at Castle-Eden, Stockton, and Bishops-Auckland; glass-bottles in large quantities are made at Sunderland, &c.

The chief rivers of this county are the Tees, the Wear, and the Derwent. The total return of income, under the influence of the property-tax bill for this county, in 1806, was 1,320,364*l*. The amount of the poor-rates for 1803, at 2*s*. 4*d*. in the pound, was 71,665*l*.

Dyeing

DYEING, *History of.* The origin of the art of dyeing is involved in that obscurity which pervades the history of all those arts connected with the common wants and necessities of life. They have originated in times beyond the reach of history or tradition, and are the offspring of the natural faculties of man directed by the great primeval wants of food, shelter, and raiment: The art of dyeing is, of course, posterior to many of these, and is founded less on the necessities than passions of mankind. A love of distinction is common to man in every stage of civilization, but that passion for admiration which is displayed in a love of finery and ornament is peculiar to him in his most barbarous and uncultivated state. Hence savage nations delight in brilliant and gaudy colours, and many paint their skins, and adorn themselves with feathers, stones, and shells of various hues. History has not furnished us even with her fables on the origin of dyeing; but from analogy, as well as observation of the practice of barbarous

nations at the present day, we may trace the rude beginnings from whence the art has sprung. The rich and gaudy plumage of birds, the finely spotted skins of animals, coloured stones, and such other substances as nature herself supplies, would afford the first materials for savage finery and dress. The caps and mantles of the chiefs of the South Sea islands, such as were brought home by captain Cook, are composed almost wholly of feathers richly coloured.

It is easy to conceive that accident must furnish innumerable instances of observation even to the eye of a savage, that many of these colours were capable of imitation, and that some substances readily imparted their colour to others. The bruising of a fruit, a flower, or leaf, is one of the most natural and obvious occurrences to which we should look for the first notion of applying vegetable juices to dyeing, and doubtless the knowledge of the tingent properties of various herbs was thus early acquired. The art, however,

must have waited the progress of industry and luxury, before it became extended and improved. Long antecedent, however, to the period when authentic history begins, it must have made considerable progress. Moses speaks of stuffs dyed blue, and purple, and scarlet, and of sheep-skins dyed red. These colours require great skill in the preparation, and the knowledge of them implies a very advanced state of the art at that period.

The colour which appears to have been earliest brought to perfection, and which was held in such high estimation among the ancients, is purple. It was to chance alone, according to the tradition of antiquity, that they owed this discovery. A shepherd's dog, instigated by hunger, having broken a shell on the sea shore, his mouth became stained with such a colour as excited the admiration of all who saw it. They endeavoured to apply it to stuffs, and succeeded. There is some discordance in the details of the ancient writers of the circumstances of this event. Some place this discovery in the reign of Phœnix, second king of Tyre, that is to say, a little more than 500 years before Christ; others, at the time that Minos the first reigned in Crete, about 1439 years before the Christian era. But the greatest number agree in giving the honour of the invention of dyeing purple stuffs to the Tyrian Hercules. He gave his first trials to the king of Phœnicia, who was so jealous of the beauty of this new colour, that he forbade the use of it to all his subjects, reserving it for the garments of royalty alone.

Some authors relate the story differently. Hercules's dog having stained his mouth with a shell, which he had broken on the sea shore, Tyras, a nymph of whom Hercules was enamoured, was so charmed with the beauty of the colour, that she declared to her lover she would see him no more till he brought her a suit dyed the same. Hercules thought of a way to satisfy his mistress; he collected a great number of the shells, and succeeded in staining a robe of the colour the nymph had demanded. Such are the different traditions handed down by the ancients of the origin of the purple dye. They are evidently blended with fiction, yet they may serve to fix the epoch of this discovery, which appears to have been made about fifteen centuries before the Christian era. Whether the purple of Tyre was similar to that mentioned in holy writ, as used by Moses for the vestments of the high priest, and the ornaments of the tabernacle, may admit of some dispute, since it is not certain, according to M. Huet, that the word *argaman*, of the Hebrew text, which all the interpreters translate by *purpura*, means in reality that colour.

The testimony of Homer confirms the antiquity of this discovery. This great poet and accurate observer, ascribes to the heroes of that age, in which we have supposed it became known, ornaments and cloths of purple.

The ancients had such an esteem for this colour, that it was especially consecrated to the service of the deity. Moses, as we have just observed, used stuffs of purple for the works of the tabernacle, and the habits of the high priest. The Babylonians gave purple habits to their idols; it was the same with most of the other people of antiquity. The Pagans were even persuaded that the purple dye had a particular virtue, and was capable of appeasing the wrath of the gods.

Purple was also the distinguishing mark of the greatest dignities from the earliest times. We have seen that the king of Phœnicia, to whom tradition says the first essays of this colour were presented, had it reserved for the sovereign. Among the presents which the Israelites made to Gideon, the scripture makes mention of purple habits found among the spoils of the kings of Midian. Homer gives us plainly

to understand, that it only belonged to princes to wear this colour; and we may remark, that this custom was observed by all the nations of antiquity.

It is not easy to give a clear and precise idea of the process followed by the ancients in the production of this highly valued colour. We find some details in the works of Aristotle and of Pliny, in whose days the practice was very common, but they are not sufficiently circumstantial. The purple dye, according to Pliny, was drawn from many species of shell fish. The best were found near the isle where New Tyre was built. They fished for them in other parts of the Mediterranean. The coasts of Africa were famous for the purple of Getulia. The coasts of Europe supplied the purple of Laconia, which was held in great esteem.

In the 36th chapter of his seventh book, Pliny ranges in two classes the different kinds of shell fish which produced the purple. The first comprehended the smaller species under the denomination of *buccinum*, from their resemblance to a hunting horn; the second included those denominated *purpura*. These Fabius Columna conceives to have been also distinguished by the generic name of *murex*, though others suppose this to have signified all the different species generally. All these several species, the chief of which are enumerated by Pliny, appear to have given colours of different shades, from which, by mixture of the liquors in various proportions, other varieties of colour were produced. A few drops only of this precious dye were obtained from each fish, by extracting a white vein placed in the throat; but to avoid this trouble with the smaller species, according to Aristotle and Pliny, the whole fish was bruised in a mortar, a practice which, according to Vitruvius, was often followed with the larger. The liquor, when extracted, was mixed with a considerable portion of salt, and suffered to remain three days; after which it was diluted with five or six times its quantity of water, and digested, moderately hot, during ten days, in a lead or tin vessel, skimming it frequently, to separate all impurities. The wool was afterwards put in, being well washed, cleansed, and properly prepared. After soaking five hours, it was taken out, carded, and again immersed in the boiling dye, till all the colour was taken up or exhausted. To produce particular shades of colour, nitre, urine, and a marine plant called fucus, of which the best kind is found on the rocks of the isle of Crete, were occasionally added.

The Tyrians, by the confession of all antiquity, succeeded best in dyeing stuffs purple. Their process differed a little from what we have related above. They used nothing to make their colour but purple shells taken out at sea. They made a bath of the liquor they drew from these fishes. They steeped their wool in this a certain time, and afterwards took it out and steeped it in another boiler, in which was nothing but buccina or trumpet fish. This is all the ancients tell us of the practice of the Tyrians. Wool, which had received this double Tyrian dye, (*diabapha*) was so very costly, that in the reign of Augustus, each pound sold for 1000 Roman denarii, about 36*l.* sterling. Nor need we wonder at this excessive price, when we consider the tedious nature of the process, and the small quantity of dye afforded by the shell fish, from each of which not more than a single drop was obtained. For 50*lb.* of wool they used no less than 200*lbs.* of the liquor of the *buccinum*, and 100*lbs.* of that of the *purpura*, or 6*lbs.* of liquor to 1*lb.* of wool. We ought not to be much surprised, therefore, that this colour vied in value even with gold itself. The ancient writers distinguish many different shades of purple. One of them, which was very dark, appears to have been a kind of violet, inclining towards a reddish hue. "*Nigrantis rose colore*

sublucens," Pliny, lib. 9. sec. 50. Another, less esteemed, was a kind of crimson. "Rubens color, nigrante deterior," lib. 9. sec. 62. The most valued of all, and in which the Tyrians particularly excelled, was a deep red purple, of the colour of coagulated blood. "Laus ei summa in colore sanguinis concreti," Pliny, *ibid.* It is in allusion to this that Homer and Virgil give to blood the epithet *purple*. There was a fourth kind known in later times, very different from those we have spoken of. The colour was whitish; an account of which may be seen in Perrault's translation of Vitruvius.

The purple has been almost every where a mark of distinction attached to high birth and dignity. It was an ornament of the first offices of Rome; but luxury, which was carried to great excess in that capital of the world, rendered the use of it common among the opulent, till the emperors reserved to themselves the right of wearing it. Soon afterwards it became the symbol of their inauguration. They appointed officers to superintend the manufactories, principally established in Phœnicia, where it was prepared solely for their use. The punishment of death was decreed against all who should have the audacity to wear it, though covered with another colour. The penalty, so tyrannically denounced against this whimsical species of treason, doubtless occasioned the loss of the art of dyeing purple; first in the West, but much later in the East, where it flourished considerably till the eleventh century.

It appears that some kinds of purple preserved their colour for a very long time. Plutarch, in his life of Alexander, relates that the Greeks found in the treasury of the king of Persia a great quantity of purple which had not lost its beauty, though it was 190 years old.

It is commonly asserted, on the authority of most of the ancient writers, that the purple had a very strong and disagreeable odour. It would appear, however, from Pliny, lib. 9. sec. 36. that this was the case only with some particular kinds. After extolling the beauty of the true purple, and allowing that it was justly an object of ambition, he asks, how it happens that the other kinds of purple, obtained from the shell-fish called *conchyliæ*, should be so high priced, considering the stinking disagreeable odour which the stuffs have that are dyed with them.

After all, the boasted purple of antiquity was a miserable dye compared with many which we now possess, and affords a strong proof of the imperfect state of the art at the period when it was held in such esteem. It was, no doubt, the most rich and brilliant colour then known.

It is a curious fact, that Mr. Bruce, whose acquaintance with ancient authors ought to have convinced him of the contrary, maintains that the Tyrian purple was produced with cochineal, and that the story of its being the blood of a shell-fish was invented and propagated by the Tyrians with a view of deceiving other nations, and keeping the art of dyeing this colour exclusively to themselves. He even adduces this as a proof of the early intercourse carried on with the new world, in times long antecedent to those in which we suppose the discovery of the continent of America was first made.

The ancients obtained from the *coccus*, now known by the name of kermes, a colour which was almost as highly esteemed as purple, and which was sometimes mixed with it. Pliny informs us it was employed in the preparation of the imperial robes. It was generally called scarlet, and was sometimes confounded with the purple. The use of the *coccus* in dyeing is very ancient, since it appears from the commentators, to be alluded to in Exodus, chap. xxxix. ver. 1. and 28.

Our materials for a history of the art of dyeing, during the ages of classical antiquity, are very scanty. Amongst the Greeks the useful arts were degraded even in the eyes of philosophers, and this contempt descended to the Romans; for Pliny, speaking of dyeing, avowedly neglects the description of operations which are unconnected with the liberal arts. "Nec tingendi rationem omisimus, si unquam ea liberalium artium fuisset."

The art of dyeing among the Greeks appears to have made no great progress; the dress of the people was of cloth which had received no dye, and which might be washed. The rich preferred coloured clothes; they esteemed such as were dyed scarlet with the kermes, but they valued still more highly those of purple.

The few details relative to dyeing into which Pliny has entered in his great work, are almost wholly confined to the purple, of which we have given an account. The few scattered facts to be met with, that serve at all to illustrate the history of the art, we shall briefly notice. Some varieties of colour, derived from the purple, and produced by different mixtures of the various kinds of shell-fish, and also by admixture with the dye of the *coccus*, or kermes, appear to have been fashionable in Pliny's time. These originated, according to our author, in the errors and failure of the dyers, who having, in the first instance, spoiled their cloth, endeavoured to hide the defects by giving it another shade: hence arose those compound twice-dyed colours which were soon held in high repute.

Besides the Tyrian purple, scarlet, and the varieties and compounds of those colours, Pliny mentions yellow as a very ancient dye, and highly esteemed in former times. The veil which the bride wore on her wedding day was of yellow, and none but women were permitted to use it. They had also a colour resembling the cyanos, or blue-bottle, and another like the golden yellow flower elichryson. None of these colours, says Pliny, were known, or at least in request in the days of Alexander the Great; for the Greek writers, who wrote soon after his decease, make no mention of them. They are evidently, however, of Greek origin, as appears from their names, which, though Greek, were current in Italy in Pliny's time.

The use of vegetable dyes appears to have been in a great measure unknown to the Romans; though the inhabitants of Gaul, according to Pliny, imitated all colours, even the Tyrian purple and the scarlet, with the juice of certain herbs. In the eleventh chapter of the thirty-fifth book of Pliny's history, is preserved a valuable notice of the process followed by the Egyptians in dyeing linen. They stained, says he, white cloth, not with colours, but with certain drugs, which have the property of absorbing them, but which exhibit no appearance of any dye till they have been boiled some time in a cauldron, from which they are withdrawn painted or stained of various colours. What is most extraordinary, says Pliny, is, that the cauldron containing only colour of one kind should impart to the cloth shades of various hues according to the nature of the drugs which were laid on, and the colours are so fixed that they can never be washed out, but are more durable and fixed than if they had never been immersed in the boiling dye.

We have here a tolerably accurate description of the process of calico printing; and the only mention in any ancient author of an art which has existed for ages past in the East, and is practised there at this day, probably with little variation from the mode described by Pliny.

The art of dyeing linen appears not to have been known in Greece before Alexander's invasion of India, where they

died the sails of his vessels of different colours. The Greeks seem to have borrowed this art from the Indians.

We may form some idea of the state of the art of dyeing amongst the Romans, from the enumeration of the different colours which were in use, and the substances employed in producing them. In addition to those enumerated by Pliny, we find, that in the equestrian games of the circus, the different divisions were distinguished by the colours *green*, color prasinus; *orange*, rufatus; *grey*, venetus; and *white*. We shall enumerate, after Mr. Bischoff, who has minutely examined the subject, the ingredients employed at that time in the art of dyeing, in addition to the two important ones already mentioned, the purple fish and coccus.

1. Alum. It is probable, from what we shall state hereafter, that the ancients were unacquainted with our alum in its state of purity.

2. Alkanet. Suidas says, that this substance was also used by women as a paint.

3. The blood of birds, which was used amongst the Jews.

4. The fucus; that of Crete was preferred, and it was generally employed as a ground or preparative for valuable colours.

5. Broom.

6. The violet, from which the Gauls prepared a kind of purple.

7. Lotos medicago arborea; snail trefoil; the bark was used in dyeing skins, and the root in dyeing wool.

8. The bark of the walnut-tree and the peel of the shell.

9. Madder. We are not certain whether the madder of the ancients was the same as ours, or another root of the same tribe.

10. Woad (glastum). This plant was undoubtedly in use among the ancients, but we do not know whether their preparation of it was the same as ours.

We are not to infer, however, that these were the only substances employed by the ancients in the art of dyeing; many more being, in all probability, in use, of which we have no account. Indigo (*indicum nigrum*) is mentioned by Pliny, and though some doubts have been entertained by his commentators respecting the true nature of this substance, some supposing it to have been Indian ink, yet it is very evident he meant the indigo of the moderns, from the purple smoke which he says it emitted when set on fire, and which we believe is peculiar to indigo. It was never, however, we believe, employed in dyeing, but simply as a pigment.

India was the nursery of the arts and sciences, which were afterwards spread and perfected among other nations. Accidents, which had a tendency to improve the art, could not fail to be multiplied rapidly in a country rich in natural productions, which requires little labour for the support of its inhabitants, and the population of which was favoured by the bounty of nature and the simplicity of manners, till it was opposed by the tyranny of succeeding conquerors. But religious prejudices, and the unalterable division into castes, soon put shackles upon industry; the arts became stationary, and it would seem that the knowledge of dyeing cotton in that country was as far advanced in the time of Alexander as it is at present.

The beautiful colours which we observe in their printed calicoes, would lead us to suppose that the art of dyeing had then attained a high degree of perfection, yet we find, from the details of those who have witnessed their operations, that the Indian processes are so complicated, tedious, and imperfect, that they would be impracticable in any other

country, on account of the difference in the price of labour. The art of printing calicoes has been practised in India at least twenty-two centuries; for the historians of Alexander's invasion of that ill-fated country speak of their flowered cloths or chintz. If they excelled therefore in the richness and brilliancy of two or three colours; it is to be attributed to the superior quality of some of their dyes, peculiar to their own country, the effect of which was perhaps heightened by the length and multiplicity of their operations. The knowledge of this art appears to have spread over a considerable part of Asia. It was practised, and is to this day, by the Persians; and we have seen that in Pliny's time, it was established in Egypt.

From the fifth volume of the "Memoires concernant l'Histoire, les Sciences, les Arts, les Mœurs, &c. des Chinois," it appears, that wool was never worn in China but as a substitute for fur, and that cotton and silk, being the only substances ever dyed by the inhabitants, received all their colours from vegetable tingent matters; that their colours were principally red, blue, violet, and what is called a woad colour; and that under the three first dynasties the business of dyeing was chiefly practised by the female part of each family, for its own particular use; and it probably continued to be practised without any thing like principle or science until near the end of the seventh century, when the Chinese discarding their own, borrowed the art and means of dyeing which were then in use among the Indians and Persians; and it is said, that alum and copperas, which the Chinese did not use before, were among the means so borrowed; a fact which renders it probable, that there was little, if any thing, in the Chinese art of dyeing, of which the loss need now be regretted.

It appears, however, that long before this time a knowledge of the uses of alum and of iron in dyeing had spread from Hindoostan and Persia westward to Egypt, and thence to Greece and Rome. Bergmann, indeed, and after him, Beckmann, have represented the alum of the ancients as different from the crystallized salt of the moderns; and have supposed that the varieties of alum mentioned by Dioscorides, were stalaclites, containing but little alum, and consisting chiefly of calcareous earth. Nature, however, does produce some, though but little, crystallized alum, particularly in Egypt and some parts of Asia; and it probably was in this state that its good effect in dyeing had been first observed, before mankind were led to the means and operations since employed for separating and collecting it from the various aluminous ores. Bergmann informs us, that the factitious salt which is now called alum, was first discovered in the eastern countries, and that among the most early works established for the preparation of alum, we may justly number that of *Roccho*, a city in Syria, now called Edessa, hence the appellation of *roch alum*. He adds, that Bartholomew Perdix, or Pernix, a merchant of Genoa, who had been at Roccho, discovered the matrix of alum in the island of Ischia, about the year 1459, and established a manufactory there; at the same time, John de Castro, who had visited the manufactories at Constantinople, discovered a matrix at Tolfa, by means of the *ilex aquifolium*, which he had also observed to grow in the adjacent mountains of Turkey; and his opinion was confirmed by the taste of the stones. The attempts made by the Genoese at Viterbium and at Volaterra succeeded extremely well; and the preparation of it in Italy soon increased wonderfully fast. The first manufactory of alum in England was established in the reign of Elizabeth, at Gisborough, by one Thomas Chaloner.

In the fifth century all the arts were lost throughout the West, except a few, which in a state of decay were preserved

in Italy; and no traces were left of knowledge, industry, or humanity.

Muratori quotes a manuscript of the eighth century, in which we find a description of some dyes, principally for skins, and some processes connected with the arts; but the Latin, which is almost unintelligible, and the chasms we find here and there, prevent us from being able to form a just idea of these processes.

The arts were better preserved in the East, where articles of luxury were procured by some of the great, even so late as the twelfth century. During the crusades, the Venetians derived their power from the barbarous mania of the age: their commerce increased; the arts were established among them, and improved by the industry of the Greeks, and spread from thence through the other parts of Italy. In the year 1338, Florence contained two hundred manufacturers, who are said to have made from seventy to eighty thousand pieces of cloth, which, as an object of commerce, were worth twelve hundred thousand crowns of gold.

It is said that archil was accidentally discovered by a Florentine merchant, about the year 1300. Having observed that urine imparted a very fine colour to a certain species of moss, he made experiments, and learned to prepare archil. He kept his discovery secret a long time; his posterity, a branch of which still exists, according to Dominique Manni, have retained the appellation of Rucellai, from oreiglia, the Spanish term for that kind of moss.

The arts continued for a long time to be cultivated in Italy with increasing success. In the year 1429, the first collection of the processes employed in dyeing appeared at Venice under the name of "*Mariegola del' arte dei tentori*;" a second edition, much improved, came out in 1510. A certain person, named Gioran Ventura Rosetti, formed the design of rendering this description more useful and extensive. He travelled through the different parts of Italy, and the adjacent countries, where the arts had begun again to flourish, in order to make himself acquainted with the various processes employed, and he published, under the title "*Plictho de l'arte de tentori*," &c. a collection which, according to Mr. Bischoff, is the first that united the different processes, and which ought to be regarded as the leading step toward the perfection which the art of dyeing has attained. This work was printed at Venice, in 1548; a French translation of it appeared at Paris in 1716. It is remarkable that in the work entitled "*Plictho*," not a word is said either of cochineal or indigo; from which we may conclude that these two dyes were either unknown or not employed at that time in Italy.

The first indigo used in Europe appears to have been brought from the East Indies by the Dutch. India was doubtless the country where that valuable substance was first produced. The uncivilized inhabitants of other countries have, indeed, discovered modes of obtaining colouring matter, very nearly resembling that of indigo, from other plants, as the *isatis tinctoria*, or woad, and the *genipa americana*, but they obtained these matters in a liquid form only, and employed them in their recent state.

The natives of India, however, went farther, they precipitated and collected, in a dry solid form, the colouring matter of indigo, and discovered the means of afterwards dissolving and applying it to stuffs. In Africa, the Mandingo negroes, according to Mr. Park, dye their cloth of a lasting blue colour, by the following simple process. The leaves of the indigo, when fresh gathered, are pounded in a wooden mortar, and mixed in a large earthen jar, with a strong ley of wood ashes; chamber-lye is sometimes added,

The cloth is steeped in this mixture, and allowed to remain until it has acquired the proper shade. In Kaarta and Ladamar, where indigo is not plentiful, they collect the leaves and dry them in the sun, and when they wish to use them, they reduce a sufficient quantity to powder, and mix it with the lye as before. "Either way," says Mr. Park, "the colour is very beautiful, and equal to the best Indian or European blue." The use of indigo was known to the Mexicans before the arrival of the Spaniards, and Clavigero, in his history of that country, gives an account of the method of obtaining it. Hernandez had long before described the plant as being indigenous in Mexico, and employed by its ancient inhabitants; and Ferdinand Columbus, in his "*Life of Christopher Columbus*," mentions it as one of the native plants of Hispaniola. What the abbé Raynal therefore asserts, of its being transplanted from the East Indies to America, can be true only of one species, the *indigofera tinctoria*, Linn. The manufacture of indigo, however, was not established in America till some time after the discovery of that country; and on the plant which produces it being recognized by the Portuguese in Brazil as identical with that from which indigo was extracted in the East Indies. The use of indigo, which was a great acquisition to the art of dyeing, was not established without considerable difficulty. It was strictly prohibited in England in the reign of Elizabeth, as was also logwood, which was ordered to be burned if found in any manufactory. This prohibition was not taken off till the reign of Charles II.

In like manner the use of indigo was proscribed in Saxony, in the edict against it, which brings to one's mind the edict against the employment of antimonial emetics; it is spoken of as a highly corrosive colour. This is a striking example of the errors into which an unenlightened administration may fall, which listens to the suggestions of interested individuals. Those who dyed blue, and were accustomed to use pastel and woad, represented that indigo would destroy the sale of those two articles, which were the produce of the country. Such a reason, which would appear specious to many, even in the present day, easily produced a prohibition which would be soon eluded by paying a tribute to the industry of other nations. The prejudice against indigo was likewise communicated to France, and Colbert's instructions forbade the use of more than a certain quantity in the pastel vats.

Cochineal was another important acquisition to the art of dyeing, for which we are indebted to the first conquerors of Mexico. The Spaniards, having observed that the inhabitants of Mexico employed cochineal in painting their houses and dyeing their cotton, gave their government an account of the beauty of the colour; and Cortes, in the year 1523, was ordered to promote the increase of the valuable insect from which it is obtained. The natural colour, however, which the cochineal gives, is but a dull colour. Soon after cochineal was known in Europe, a great chemist of the name of Kuster, Kuffler, or Kepfler, found out the present process for dyeing scarlet by means of a solution of tin, and carried the secret to London in the year 1543. See COCHINEAL and SCARLET.

The ancients applied the name scarlet to the colour obtained from kermes, which was much inferior in beauty to the colour we distinguish by that appellation. We probably know how to employ the kermes to greater advantage than they did, since we possess a pure alum which disposes the stuff to receive a more beautiful and durable colour; yet our dyers have almost entirely discontinued the use of it, because they can obtain from cochineal a colour beyond all comparison more beautiful. The supposition, that the

colour which we obtain from kermes is preferable to that obtained by the ancients, is supported by the testimony of Pliny, who insinuates that it was not a durable colour; now the colour we give by means of kermes to wool prepared with alum, is exceedingly durable. The discovery of scarlet may be considered as the most important era in the art of dyeing, as it introduced to our knowledge the solution of tin, since so variously and happily applied. A Flemish painter, called Gluck, got possession of this secret, and communicated it to Gobelin. The knowledge of the process afterwards spread throughout all Europe. Gluck travelled into the East, where there were still some remains of Grecian industry, and afterwards settled in Flanders, where he spent a long and prosperous life. According to Mr. Francheville, this man, who had been so useful to his country, died about the year 1550.

For a long time Italy, and especially Venice, possessed the art of dyeing almost exclusively; a circumstance which contributed to the prosperity of their manufactures and commerce: by degrees it was introduced into France. Giles Gobelin, to whom the process for making the true scarlet had been communicated, established a manufactory in the place which still bears his name; and this undertaking was deemed so rash, that it was termed *Gobelin's folly*.

The attention of the Royal Society appears to have been early directed to the improvement of the art of dyeing. At a meeting of that learned body on the 30th of April, 1662, Mr. Hook was desired to translate into English, a work on dyeing, which appears to have been that already mentioned under the title of *Plietho*. On the same day also, sir William Petty, one of its earliest and most active members, in consequence of a previous request from the society, brought in "An Apparatus to the History of the common practices of Dyers," which was afterwards printed in "Dr. Spratt's History of the Royal Society," and seems to have been the first work published in the English language on the processes and operations of dyeing. Nearly two years afterwards Mr. Boyle presented to the society his "Experiments and Considerations touching Colours." And on the 10th of August, 1664, it was ordered by the society, "that the way of *fixing colours* should be recommended to Mr. Howard, Mr. Boyle, and Dr. Merritt." These, and especially the two first, were amongst the most distinguished members of the society; but it does not appear that any thing deserving of notice was done in consequence of this recommendation. However, at a meeting of the society on the 11th of November, 1669, that very ingenious and useful member, Mr. Hook, produced a piece of calico stained after the way contrived by himself, which he was desired to prosecute in other colours besides those that appeared in this piece; and accordingly on the 9th of the following month, Mr. Hook produced another specimen of staining with yellow, red, green, blue, and purple colours, which he said would endure washing with warm water and soap. But from this time it does not appear that any thing considerable was done for nearly the space of a century by men of science in this country towards the improvement of the arts of dyeing and calico printing.

In France, however, the minister Colbert, anxious to extend the commerce and manufactures of his country, which had languished during the stormy administrations of Richlieu and Mazarin, turned his attention particularly to the art of dyeing. He invited the most skilful artists, rewarded their talents, and established many manufactories; and it is curious to remark, that those of Vauvobais and Sedan were called, in the letters patent which were granted them, manufacturers of fine cloth after the Dutch and

English fashion. In 1672, he published a Table of Instructions for Dyeing, under the title of "General Instructions for dyeing Wool and woollen Manufactures of all Colours, and for the Culture of the Drugs or Ingredients employed in them." This, however, was not intended merely to diffuse information, but as a legislative act, to controul the dyers in their operations. This work merits attention; we shall first notice the reason which he gives for considering the subject as one of great importance.

"If," says Colbert, "the manufactures of silk, wool, and thread are to be reckoned amongst those which most contribute to the support of commerce, dyeing, which gives them that striking variety of colour by which they resemble what is most beautiful in nature, may be considered as the soul of them, without which the body could scarcely exist. Wool and silk, the natural colour of which rather indicates the rudeness of former ages, than the genius and improvement of the present, would be in no great request if the art of dyeing did not furnish attractions which recommend them even to the most barbarous nations. All visible objects are distinguished and recommended by colours, but for the purposes of commerce it is not only necessary that they should be beautiful, but that they should be good, and that their duration should equal that of the materials they adorn."—But Colbert, though he instituted many useful regulations for the instruction of the farmer and the artill, imposed a system of prohibition and restraint so excessive, as almost to bar all future improvement. He divided the dyers into two classes, to one of which were confined the colours deemed durable and fixed, whilst the other class was allowed only to meddle with those which were considered fugitive. In the dyeing of black cloth he insisted that the operation should be begun by the dyers in grain, or those who gave the durable colour, and finished by those who produced the false one. Each was confined to a certain number of ingredients, and neither were suffered to have Brazil wood, and various other articles. The bad effects of this prohibition were moderated by the facility of eluding it, and by the rewards bestowed on those whose experiments promoted the progress of the art, and whose discoveries were afterwards to be published, and to modify the existing regulations.

French industry lost its pre-eminence by the criminal revocation of the edict of Nantz, which carried desolation into her manufactories, and dispersed her workmen, and the knowledge of her arts, throughout all Europe.

Since that time the department of administration, charged with the superintendence of the arts and manufactures, has constantly sought to repair those errors, and to encourage industry and exertion by the diffusion of knowledge, which, under wise laws, is the most efficacious means that can be employed.

Dufay, Hellot, Macquer, and Berthollet, have been successively charged with the care of improving the art of dyeing; and to their labours all Europe is indebted for most valuable acquisitions.

Dufay amended, or rather superseded, the "Instructions, &c." of Colbert, by the publication of a new one, under the administration of M. d'Orry, in 1739. He appears to have been the first who entertained just, though incomplete, ideas of the true nature of colouring substances, and the cause of their adhesion to stuffs when dyed. In his "Observations physiques sur le melange de quelques couleurs dans le teinture," Mem. de l'Academ. 1737, he observes, that colouring particles are naturally disposed to adhere, more or less firmly, to the filaments which receive them; and he remarks very justly, that without this disposition

stuffs would never assume any colour but that of the bath, and would always divide the colouring particles equally with it; whereas the liquor of the bath sometimes becomes as limpid as water, giving out all the colouring matter to the stuff, "which seems to indicate," says he, "*that the ingredients have left attraction for the water than for the particles of the wool.*" He also noticed, *the difference in the degree of attraction which different substances, as wool and cotton, exert on the same colouring matters, and which* he found so great, that a skain of each having been in an equal degree subjected to the operation for dyeing scarlet, the woollen yarn was found to be fully and permanently dyed, while the cotton retained all its former whiteness. Yet these facts, important as they were, to the foundation of a theory of the art of dyeing, were unproductive in his hands; for though satisfied with the explanation they offered of many phenomena, yet they left, says he, so much to be wished for, that he would relinquish it readily, if a more probable one could be found. He appears to have had no idea of the other and more important cause of the permanency of colours, that which arises from the use of mordants, or the interposition of a suitable basis, possessing a particular attraction both for the colouring matter and dyed substance, and acting as a bond of union between them. He examined, with great sagacity, certain processes, and established the surest methods that could at that time be employed for determining the goodness of a colour, and this he did in an easy and familiar manner. His labours, on the whole, entitle him to the gratitude of posterity, and he may justly lay claim to the merit of having first discovered and enunciated the facts, and of having drawn some partial conclusions from which the true theory of dyeing was some years afterwards clearly and luminously deduced.

He was succeeded by Hellot, to whom we are indebted for one of the best practical treatises on the art of dyeing wool and woollen cloths now extant. This work is valuable for the accuracy with which the numerous processes are described: without profiting, however by the hints thrown out by his predecessors, he suffered himself to be misled by a vague and groundless hypothesis, on the cause of the adhesion of the colouring particles to the substance dyed, the action of mordants, and the difference between the true or durable, and false or fading dyes. Of his theoretical ideas, and the principles he laid down, some judgment may be formed from the following passage taken from his work. "I believe it may be laid down as a general principle in the art of which I am now treating, that all the invisible mechanism of dyeing consists in dilating the pores of the body to be dyed, in depositing in them particles of foreign matter, and retaining them there by a kind of covering not liable to be affected by water, rain, or the rays of the sun; in choosing colouring particles of such a degree of fineness as to be rendered sufficiently fixed in the pores of the stuff opened by the heat of boiling water, and again constricted by cold, and also coated by the kind of varnish which the salts, employed in its preparation, had left in those pores; whence it follows that the pores of the fibres of the wool which has been wrought, or is to be wrought into cloth, should be cleansed, enlarged, coated over, and then constricted, so that the colouring particles may be retained in them nearly in the same manner as the diamond is retained in the collet of a ring." He fancied that he could discern in every dyeing process some means by which sulphate of pot-ash, then called vitriolated tartar, might be formed; and this neutral salt not being readily soluble by cold water, nor air, nor light, he conceived the whole art of dyeing to consist in first dilating the pores of the substance

to be dyed, so as to procure a copious admission of colouring matter, divided by a suitable preparation into atoms, and then wedging or fastening these atoms within the pores of the dyed substance, by the small particles or crystals of this difficultly soluble salt. Upon this *mechanical hypothesis*, he supposed that alum became useful in dyeing, not by the pure clay or alumine which it contains, but by furnishing sulphuric or vitriolic acid, to assist in forming the sulphate of pot-ash, which was to perform the important function of wedging or fastening the colouring atoms. But though nothing could be more groundless than such a theory, the learned in all countries appear to have been satisfied with it for a considerable length of time, it being always less troublesome to believe than to make experiments.—Macquer followed next. He has given us an exact description of the processes employed in dyeing silk, and his practical treatise, published in 1763, is held in deserved estimation. He has made us acquainted with the combinations of the colouring principle of Prussian blue; he has endeavoured to make an application of it to the art of dyeing, and has given us a process for communicating the most brilliant colour to silk, by means of cochineal. Macquer intended to have published a general treatise on the art of dyeing, the prospectus of which he issued in the year 1781, but the indisposition which so long preceded his death, prevented his engaging in it, and he died in 1784, before he had been able to carry into effect any part of his plan. It is surprising that Macquer, who was an excellent chemist, and amongst the first who entertained correct ideas of the nature of chemical affinity should have been seduced by the hypothesis of Hellot. "I should now," says he in his treatise on dyeing silk, "explain the action of mordants, and unfold the causes of durable and fading dyes; but this subject has been treated with such sagacity by Mr. Hellot, that I shall refer the reader to him." Bergmann seems to have been the first who referred the phenomena of dyeing *entirely* to chemical principles. Having dyed some wool and silk in a dilute solution of indigo in sulphuric acid, he explains the effects he observed in the operation, by attributing them to the precipitation occasioned by the blue particles having a stronger attraction for the particles of the wool and silk than for those of the acidulated water: he remarks, that this attraction of the wool is so strong as to deprive the liquor entirely of the colouring particles, but that the weaker attraction of the silk can only diminish the proportion of those particles in the bath; and he shews that both the durability of the colour, and the degree of intensity it is capable of acquiring, depend on these different attractions. This is the true light in which the phenomena of dyeing, which are purely chemical, should be considered. Dufay had advanced thus far, but overlooked the importance of his own simple truths, in the search after more recondite and complicated causes. But the peculiar action of mordants was still unexplained, except on the wild hypothesis of Hellot, till our countryman Mr. Keir, the ingenious translator of Macquer's Chemical Dictionary, suggested, "that in dyeing, the earth of alum was precipitated, and in this form attached to the material prepared or dyed." Macquer soon after adopted the opinions of Bergmann and Keir, and in the second edition of his dictionary, under the article *Dyeing*, published in 1778, treated the subject in a more extended manner, and proved that he had formed just conceptions of the nature and uses of alum, and of different metallic solutions, as mordants in dyeing. Berthollet succeeded next to the place of trust which had been successively held by Dufay, Hellot, and Macquer, a post which he has held, and still holds, with distinguished honour to himself, and

advantage to his country. In a series of memoirs, inserted in the *Transactions* of the academy, the *Annales de Chimie*, and *Journal de Physique*, he has examined various points of chemical theory connected with the art of dyeing, and almost all his labours have since been directed to this object. In 1791, he published his elements of the art of dyeing in 2 vols. 8vo. a work which has contributed more to the progress of true theory and the general improvement of the art, than any other treatise whatever. This work has been translated into English by Dr. Hamilton, and a second edition of the original, with considerable additions, appeared in 1803. Every thing which a liberal and enlightened government could do for the encouragement and progress of the art, has been done in France, and this solicitude has been crowned with the success it merited. Mr. Anderson attributes the superiority which certain articles of French manufacture maintain over those of other nations, who possess the most beautiful wool, to the perfection of their dyes; and Mr. Home is of opinion, that the French are indebted to the academy of sciences for their superiority in many of the arts, and especially that of dyeing. Perhaps another cause of the alleged superiority of the French over other nations in the art of dyeing, may be discovered in the peculiar nature of their manufactures. Silk, of all other substances, seems best adapted to the display of fine and brilliant dyes, and it constitutes, in all its various forms, a large portion of the manufactures of France. We may look, therefore, to the dye-houses of Lyons, as well as to the academy of sciences, for the cause of that superiority which is now gradually declining. We have already spoken of our countryman Mr. Keir, as the first who suggested the true theory of mordants, which was afterwards extended and improved by Macquer. The worthy president of the literary and philosophical society of Manchester, Mr. Henry, some time after, read a paper to the society, since published in the 3d volume of their *Memoirs*, "On the nature of wool, silk, and cotton, as objects of the art of dyeing; on the various preparations and mordants requisite for these different substances, and on the nature and properties of colouring matter." This paper, which is replete with new and ingenious views of the nature and objects of dyeing, may be considered as amongst the first attempts in this country to reduce to system and theory the subject of which it treats: Mr. Henry, in these *Memoirs*, first pointed out the peculiar nature of the aluminous mordant of the calico printers; he shewed that by double decomposition an acetate of alumina was formed, and explained the cause of its superiority over the sulphate of alumina, which consists in the substitution of a volatile vegetable acid in lieu of the sulphuric.

In the year 1794, Dr. Bancroft published his "Experimental Researches concerning the philosophy of permanent colours, and the best means of producing them by dyeing, calico printing, &c." which may be considered as the first, and indeed only original work on the subject which this country has produced. This work, as the title indicates, is rather an experimental than practical treatise: it contains, however, much valuable information, which the practical dyer may apply in many cases with considerable advantage, and is also useful as containing a history of all the different substances of which it treats, and an account of the labours of Macquer, Dufay, Hellot, Berthollet, and others, in this field of science. It is to be regretted, that the work is still imperfect, the first volume only having yet appeared. The second, which was intended to comprehend all the remaining adjective colours and colouring matters, not treated of in the first, particularly those very interesting ones which

are derived from the tribe of madders, can hardly, after an interval of fifteen years, be looked for with confidence.

Dr. Bancroft first pointed out the true action of tartar in the process for dyeing scarlet, and clearly proved that the nitro-muriate of tin, or any solution of tin alone, produced a crimson only; and that the addition of tartar produced a scarlet, by the conversion of a portion of the crimson colouring matter of the cochineal, to a pure yellow. On this observation he founded an improvement in the scarlet dye, which consisted in communicating to the cloth, by means of quercitron bark, and any suitable mordant, such a shade of yellow as would produce, with the crimson of the cochineal, a true scarlet. By this process he expected to save all that cochineal which he conceived to be expended in the production of the yellow: the trials on the large scale, however, we are informed by Dr. Bancroft, did not justify the expectations he had formed, of the importance of the process.

A more important and lasting service, however, he has rendered to the art of dyeing, by the introduction of the quercitron bark, a drug which is now become of such general and acknowledged utility, as to supersede almost every other kind of yellow colouring matter whatever. For the history of this substance, and other particulars respecting its introduction, we must refer to the article itself, under the head *QUERCITRON BARK*.

Though we have to record no brilliant discoveries or improvements in the practice of dyeing, within these few years, yet the art has continued progressively to improve, the different processes have been simplified and amended; and what some years ago was considered a matter of chance and uncertainty, is now reduced to fixed principles.

The dyeing of Turkey red is now fully understood and practised in this country, with a success at least equal to that of any other. The process has, with some modifications, been applied lately to the dyeing of piece goods, and the red thus produced surpasses in beauty and durability, all other colours which it is possible to fix on cotton. But it is not our intention here to enter into a history of all the minor improvements that have been made in the art of dyeing; they will be treated of at large, during the progress of the work, under their respective heads.

DYEING, the Laws relating to, are as follow: Dyers shall dye both the cloth and the lilt, or forfeit it. 1 R. III. cap. 4. No dyer may dye any cloth with archil, or with brazil, to make a false colour in cloth or wool, &c. on pain of twenty shillings. Stat. 3 & 4 Edw. VI. cap. 2. Dyers are to fix a seal of lead to cloths, with the letter *M*, to shew that they are well maddered, &c. or forfeit three shillings and fourpence; and not to use log wood in dyeing on pain of forfeiting twenty pounds. Stat. 23 Eliz. cap. 9. And penalties are inflicted on dyers, who dye any cloths deceitfully, and not being dyed throughout with woad, indigo, and madder; also marks shall be put to the cloth dyed, &c. Dyers in London are subject to the inspection of the Dyers' company, who may appoint searchers; and out of their limits, justices of peace in sessions to appoint them: opposing the searchers incurs ten pounds penalty, by stat. 13 Geo. I. c. 24.

DYEING, in a more extensive sense, is applied to all kinds of colourings given to bodies of any sort.

In which sense, dyeing amounts to the same with *coloration*; and includes staining, painting, gilding, marbling, printing, &c. The Chinese are said to practise the dyeing of tea with catechu, which gives the worst sorts of green tea leaf the colour, and its infusion the tincture of bohea. Short. Dissert. on Tea, pref. p. 15. See *TEA* and *CATECHU*.

The sorts of dyeing now commonly used in vulgar trades, are 1. Whitening of wax, and several sorts of linen, and cotton cloths, by the sun, air, and reciprocal effusions of water. See BLEACHING. 2. Staining of wood and leather by lime, salt, and liquors, as in staves, canes, marble, leathers, marquetry, &c. 3. Marbling of paper by tempering the colours with ox-gall, and applying them upon a stiff-gummed liquor. See PAPER. 4. Colouring, or rather discolouring silks, tiffanics, &c. by brimstone. 5. Colouring several iron and copper works into black with oil. 6. Giving leather a gold colour, or rather dyeing silver-leaves like gold, by varnishes; and in other cases by urine and sulphur. 7. Staining of marble and alabaster, with heat, and coloured oils. 8. Tinging silver into brass with brimstone or urine. 9. Colouring the barrels and locks of guns blue and purple with the temper of small-coal heat. 10. Colouring glass crystals, and earthen-ware with the rusts and solutions of metals. See POTTERY, &c. 11. Colouring live hair, as in Poland, both horse and man's hair; and also of furs. 12. Enamelling and annealing. See ENAMELLING. 13. Application of colours, as in the printing of books and pictures; and the making of playing cards, jappanning, &c. See PRINTING, CARDS, and JAPPANNING. 14. Gilding and tinning with mercury, block tin, and sal ammoniac. See GILDING and TINNING. 15. Colouring metals, as copper with calamine into brass, and with zinc or salt-petre into false gold, or into false silver with arsenic. See CALAMINE, BRASS, ZINC, ARSENIC, &c. 16. Making painters' colours, by preparing of earth, chalk, and slates, as in umber, oker, Cologne earth, &c. out of the calces of lead, as ceruss and minium; by sublimes of mercury and brimstone, as in vermilion; by tinging of white earths variously, as in verditer, and some of the lakes; by concrete juices or sæculæ, as in indigo, pinks, sap-green, and lakes: and by rusts, as in verdigris, &c. See CERUSS, MINIMUM, VERMILLION, INDIGO, &c. 17. The applying of these colours by the adhesion of ox-gall, as in the marbled paper aforesaid; or by gum-water, as in limning: or clammy drying oils, as the oils of linseed, nuts, spike, turpentine, &c. See PAINTING, LIMNING, &c. 18. Watering of tabbies. See WATERING, CALENDER, TABBY, &c. Petty. Appar. Hist. of Dyeing, ap Sprat.

Glass dyed is the common matter of artificial jewels: the tinctures are given with zaffer, manganese, feretto, crocus martis, &c. The processes are described at length in Antonio Neri, de Re Vitrary, lib. i. cap. 12, 13, 14, &c. See GLASS, GEM, &c.

The Peruvian women, when grown old, dye their grey

hairs black by a very untoward operation, viz. holding the head some hours with the hair lopped in a boiling tincture of the root of a tree called *cuchau*, by the Spaniards *maquey*.

DYEING of Hats, is done by boiling a hundred pounds of logwood, twelve pounds of gum, and six pounds of galls, in a proper quantity of water for some hours; after which about six pounds of verdigris, and ten pounds of green vitriol are added, and the liquor kept simmering, or of a heat a little below boiling. Ten or twelve dozen of hats are immediately put in, each on its block, and kept down by cross bars for about an hour and an half; they are then taken out and aired, and the same number of others put in their room; the two sets of hats are then dipped and aired alternately, eight times each; the liquor being refreshed each time with more of the ingredients, but in less quantity than at first. This process affords a very good black on woollen and silk stuffs as well as on hats. Com. Phil. Tech. p. 428. See HAT.

DYEING, or staining of wood, for inlaying, veneering, &c. Red is done by boiling the wood in water and alum; then taking it out, adding brazil to the liquor; and giving the wood another boil in it. Black, by brushing it over with logwood boiled in vinegar, hot; then washing it over with a decoction of galls and copperas, till it be of the hue required. Any other colour may be given by squeezing out the moisture of horse-dung through a sieve; mixing it with dissolved roch alum, and gum-arabic; and to the whole adding green, blue, or any other colour designed. After standing two or three days, pear-tree, or other wood, cut to the thickness of half a crown, is put into the liquor boiling hot, and suffered to remain till it be sufficiently coloured. Park. Treat. of Japan. chap. xxvii. p. 82.

DYEING of bone, horn, or ivory. Black is performed by steeping brals in aqua fortis till it be turned green: with this the bone, &c. is to be washed once or twice; and then put in a decoction of logwood and water, warm. Green is begun by boiling the bone, &c. in alum-water; then with verdigris, sal ammoniac, and white wine vinegar; keeping it hot therein till sufficiently green. Red, is begun by boiling it in alum-water, and finished by decoction in a liquor compounded of quicklime steeped in rain-water, strained, and to every pint an ounce of brazil wood added: the bone, &c. to be boiled therein till sufficiently red. Other methods are given by Salmon. And from him by Houghton. Park. lib. cit. p. 83. Salm. Polygraph. lib. iii. cap. 35. p. 275. Hought. Collect. N^o 138. tom. i. p. 361. See BONES, HORN, IVORY, &c. The refuse of the Bow-dye, given to hogs to feed on, is said to tinge their very bones red.

Dynamometer

DYNAMOMETER, (from *δυναμις*, *power*, and *μετρεω*, *I measure*, meaning a measurer of power,) is the name of an instrument intended for measuring the muscular strength of men and other animals. An instrument of this kind was, some years ago, invented by Mr. Graham, and was afterwards improved by Dr. Defaguliers; but it was too bulky, and too limited in its use; so that it was soon neglected. Mr. Le Roy of the Academy of Sciences at Paris, constructed, soon after, a much more useful instrument for the same purpose. It consisted of a metal tube about a foot long, placed vertically on a foot like that of a candlestick, and containing in the inside a spiral spring, having above it a graduated shank terminating in a globe. This shank, together with the spring, sunk into the tube more or less, in proportion to the weight which pressed upon the globe at the top of the shank, and the graduation of the latter indicated the quantity of it. Therefore, when a man's strength was to be tried by means of this instrument, the man needed only press upon the above-mentioned globe with all his power, and the graduation of the shank indicated the quantity of that power, *viz.* it shewed the number of pounds weight to which it was equivalent.

Mr. Regnier, at Paris, at the instigation of Messrs. Buffon and Gueneau, contrived another sort of dynamometer. It consisted chiefly of an elliptical spring a foot long, and rather narrow. It was covered with leather, that it might not hurt the hand which compressed it. The strength of this spring was such as to exceed that of any animal to which it might be applied; and it contained an index with a mechanism which indicated how much it was compressed; or, which is the same thing, it indicated the quantity of the power which compressed the spring. Therefore, when a person wished to measure his power by means of this machine, he was obliged only to compress the elliptical spring with all his force, and to observe the quantity of that force as pointed out by the index of the machine. (See *le Journal de l'Ecole Polytechnique*, vol. ii.) Both the use and the construction of the last described machine were much extolled; but, upon a strict examination, it does not appear that it was superior to Le Roy's contrivance.

Since the above was made public, nothing peculiarly useful has been offered for the purpose of measuring the strength of animals. Yet upon the whole it seems, that the common well known spring steel-yard, though not intended expressly for that purpose, is the best instrument for measuring the strength of men and other animals. In principle, it is nothing more than Mr. Le Roy's contrivance; but under a much more commodious form. It has a ring at one end, and a hook at the other. By endeavouring to pull those parts

from each other, a graduated rod comes out of the external tube, and shews the force which has been applied to it. Therefore, by fastening the ring to an immovable object, and the hook to a man, or horse, &c. by means of a rope or otherwise, the strength of the man or other animal may be easily ascertained. See **SPRING STEELYARD**.

It certainly is a desirable thing to know the various muscular power of men and animals, especially of such as are to be employed for work of various kinds; and upon the whole a pretty good estimate may be obtained from the use of the above-mentioned machine. Yet, it must be observed, that a determination of this kind is influenced by a variety of circumstances, which tend to render the result inaccurate or equivocal. For instance, a man is much stronger than another man in his hands, whilst that other man is much stronger than the former in his legs. One can carry a great weight upon his head; another can pull a great weight after him, that is, drag it over the ground, and so forth. Nearly the same thing may be remarked with respect to other animals. But the most material circumstance is the duration of the exertion, *viz.* certain men, and especially such as are young and well fed, but not much used to work, are capable of immense exertion during a minute, or an hour, or even a day; but they are incapable of enduring a longer duration of labour; whilst others go on with a uniform daily exertion during weeks and years. The same variety in the length of the exertion takes place in other animals, especially such as are more commonly used for labour, *viz.* horses, mules, oxen, camels, &c.

Fig. 1. Plate XXVI. Mechanics, represents one of the whippetrees, to which two horses or oxen can be applied, the cover of the mechanism being removed to explain its internal structure. A A is the main whippetree, having a hook at *a* to back it to the plough, &c., and two others to connect it with two short whippetrees B, B, by which the cattle draw; the hook *a* is fastened to a straight bolt *b*, sliding freely through holes in two pieces of iron plate *d, f*; a pin is put through the end of the bolt to prevent it being drawn quite through at *e*; a circular plate of iron is pinned fast upon the bolt *b*, between which, and the fixed plate *d*, a spiral steel spring is placed, which has a strong tendency to elongate itself, and draw the hook to the machine: *b* is a short rack fastened to the iron plate *e*, and turning a small pinion on the back of the index *i*, which points out the divisions on the arc *k*. The divisions are made by suspending weights from the hook *a*; these compress the spring in proportion to their weight, and the rack moves the index *i*; the value of each weight being marked on the arc *k* at the place pointed out by the index *i*.

of course, when the horses are harnessed to the whippetrees B, B, and the plough, or carriage, to the hook *a*, the motion of the index denotes the force of their draught.

Fig. 2. is another machine on the same principle as the last, but is contrived so as to require a very delicate spring, which is found to be more sensible than a large one, and to keep its elasticity longer: this is accomplished by having the hook *a* formed into two eyes at the other end, to receive the pivots of the lever *b*, whose fulcrum, or fixed centre, is at *d*; at the other end of the lever it is connected by a short iron link *e*, to a second lever *f*, of which *g* is the fulcrum: *b* is the spring barrel, exactly the same as the other machine, but much smaller, being only to weigh about 50*lb.* instead of 5*cwt.*; its spindle is attached to the lever *f*, and is moved thereby when the hook *a* is drawn: the spindle of the spring has a rack fastened to it, which moves a small pinion, on whose arbor the index to the dial-plate is fixed: the dial plate is in this machine a whole circle, described in the figure by a dotted circle, with large divisions for hundred weights, and subdivisions for the quarters. By means of the levers the power exerted on the hook is so far diminished, that the small spring of 50*lb.* will serve to weigh a quantity equal to 6*cwt.*; and by increasing the spring a little, and altering the levers, by throwing the hooks nearer the centres, and lengthening the levers, it may be made to do for 12*cwt.* The mechanism is covered over with an iron box, to defend it from injury.

This machine is the invention of Mr. Robert Salmon, Woburn, Bedfordshire, and they are now manufactured by Mr. Shepherd, implement-maker, Woburn.

This article is also the most proper place to describe a method, employed by Mr. Salmon, to measure the force requisite to give motion to a threshing and flour mill at Woburn-Park farm, belonging to the duke of Bedford. The mill was originally worked by a horse-wheel, adapted for eight horses or oxen, though it is now worked by a steam-engine; but the horse-wheel still remains. It is represented in fig. 3, where A A is the main vertical shaft, having pivots at both ends, one of which works in a brass socket, supported on beams, *a, a*, laid on the ground; and the other in a brass bearing, bolted to the *a* beam, which is framed between two girders, B, B, of the floor above. D is the rim of the wheel, containing the cogs; it is composed of three thicknesses fastened together, and is supported by sixteen arms, F, from the enlarged part of the shaft at E, and braced by sixteen beams, L, extending from the lower part of the shaft to the middle of the arms. The horses or oxen draw from upright pieces of wood, *a, a*, bolted to the arms, F, and braced by long iron bars from the adjoining arms. Eight of the arms are furnished in this manner, for the oxen to work the wheel: they walk upon a circular road at G G, on the level of the ground, while the shaft is sunk in a pit walled round, to give a greater length

of shaft, that the oblique braces may have more effect.

The method in which Mr. Salmon applied a dynamometer to this wheel was as follows: a piece of board, *b*, was extended between and nailed to the two uprights, *a, a*, by which the oxen drew; in the middle of the board a large pulley, *g*, was fitted, turning very freely, and upon a small pivot as was consistent with strength; another pulley, *d*, was suspended from the arm of the wheel near the centre; a small soft rope was passed over both pulleys, hanging straight down from the pulley, *d*, and terminating in a double hook, and after passing round the pulley, *g*, was tied to the middle of a short round stick. Four of the arms were fitted up in this manner, and two men were placed at each, holding the stick in their hands behind them. Mr. Salmon placed himself in the pit, being provided with a number of weights, some of which he hooked on the hooks at the end of the rope. He then directed the men to proceed forwards, in the track formed by the feet of the cattle, drawing the rope after them. Their action raised the weights, and caused the wheel to follow; but where the weights were drawn up towards the pulley *d*, Mr. S. added more weight, until it was so adjusted that the wheel moved round with its proper velocity, without the weights rising or falling above any point at which they were placed. The sum of these weights now shewed the power required to move the mill; and the motion might be continued as long as was necessary to obtain a fair result. By this method, any sudden jerk or exertion, which the men might make, would not be communicated to the wheel, as it would only draw up the weights, which would descend again, when the men relaxed their strain.

The mill was employed in threshing; and as this is a very unequal kind of work, it was often necessary to hook on more weights, to overcome the resistance occasioned by feeding the machine: for it must be observed, that no more power could be applied to the wheel than the sum of the weights, as it was only through the medium of horses that the men exerted any power at all upon the wheel.

The velocity of the wheel also depended upon the weights, for the heavier they were the quicker it would follow the men, who were directed to move at such a pace, as the wheel seemed to take, that the weights might not descend by their going too slow, or ascend by their going too fast. The wheel's velocity was measured by a watch which Mr. S. had in his hand; and each turn of the wheel was denoted to him, by a nail which was drove in the rim of the wheel striking a piece of tin plate nailed up against the wall. If he found by the watch the wheel was moving too slowly, he applied more weight, or *vice versa*, until the proper weight was found. Mr. Salmon made many experiments in this manner, on the force required to thrash different kinds of corn, of which we shall give the results under **THRASHING MILL**.

Eliquation

ELIQUATION, or LIQUATION, in *Metallurgy*, is an ingenious process of separating silver from copper by means of lead, which appears now, however, to be very little employed; but a short account of it may be here given.

When rough unrefined copper contains silver in the proportion proper for this operation, it is first melted with a large quantity of lead, and the mixed alloy is cast into loaves or conical masses. These are then set in a furnace on an inclined plane of iron, with a small channel grooved out and heated to a degree just below that of the melting point of the alloy, during which the lead melts, or, as it were, sweats out of the loaf, carrying with it the silver, and the copper is left behind as a reddish black spongy mass. This last is properly the process of *eliquation*. The silver-holding lead is then purified on a cupel, in the way which will be described under the article *SILVER*.

Eliquation can only be performed with certain proportions of the three metals concerned in the process. According to Cramer (*Docimasia practica: processus* 48), every half ounce of silver requires 17 lbs. (or 344 times its weight) of lead for its extraction from copper by a single *eliquation*; and on the other hand, the lead should not be more than about four times the weight of the copper, otherwise the mass will prove too fusible, and the whole loaf will melt down at the heat necessary for the extraction of the lead and silver. On the other hand, if the lead is less than about $2\frac{1}{2}$ times the weight of the copper, the loaf of *liquation* will not yield all the lead in one process, and much of this metal, and along with it part of the silver, will remain after the operation.

The above data (allowing four times as much lead as copper) would therefore give for the due proportions of the alloy 544 parts of lead, 136 of copper, and one of silver. Other metallurgists diminish the lead somewhat, making it to the copper only as 11 to 3.

The whole process of *liquation* is described at length in a valuable paper by Duhamel, in the *Memoires de l'Acad.* for 1788, from which the following is a short extract.

The lead and crude silver-holding copper, being duly proportioned, are thrown into a high blast furnace, the floor of which is lined with a mixture of clay and charcoal, rammed hard, and laid in an inclined direction, so as to convey the melted metal into a separate receptacle. The crude copper is first broken in small pieces when hot, and assayed, to determine the proportion of silver. Either lead or litharge is used in the mixture; if the latter, it is mixed with charcoal to promote its reduction, and 120 parts of the litharge are taken as equivalent to 100 of lead. The furnace being first heated by itself for some hours, a basket full of the scoræ from the first reduction of the copper ore is thrown in, which soon melts, and forms a vitreous glazing, that protects the walls of the furnace from the violent action of the blast. The mixed metals are then thrown in at intervals, and the whole soon melts into a triple alloy, which flows

into the receptacle, whence it is tapped out into iron moulds, whereby it assumes the conical shape requisite for the subsequent *eliquation*. The heat required in this first operation is much less than that at which copper melts, so that the fusion and reduction of the litharge go on speedily, and in a well-managed furnace, seven loaves of *liquation*, each weighing about 350 lbs., may be cast in an hour.

The next process is the *eliquation*, which is performed in a furnace constructed for the purpose, usually holding six loaves, set on iron bars, separated from each other by bricks, and having a channel beneath to convey the silver-holding lead into a basin as it melts out. The management of the heat is here of great importance. If the process goes on well, the lead flows out easily, and the loaves gradually sink down, and become honey-combed, without losing any sensible portion of their copper. If the heat is too great, particles of copper are visibly carried down with the lead, which must be immediately prevented by slackening the fire. When the lead has ceased to flow, the loaves are taken out, and when cold have a dark red colour and a crumbly texture. It requires about four hours to *eliquate* the loaves. The first portion of the lead is always the richest in silver, but whatever care is taken in the process a little of both silver and lead remains, together with part of the iron, arsenic, and other impurities of the copper.

To collect the small remaining portion of silver, a number of the porous loaves remaining after *liquation* are ranged in a kind of oven so as nearly to fill it, and are made moderately red-hot by the flame of wood drawing through it, by which a quantity of mixed metal and scoræ drops down on the hearth, consisting of lead holding a little silver, of iron, sulphur, arsenic, some copper, and scoræ. This mass is washed in a stamping machine, by which the scoræ are got rid of, and the metals alone remain, which undergo a further purification. When the dropping from the oven-furnace begins to be red and compact, it is a sign that all that is heterogeneous to the copper, which can be extracted in this way, is got out, and the copper itself begins to melt. The loaves are then taken out, and appear varnished with a thick vitrescent mass, which, on dropping them into cold water, cracks in every direction, and when cold, may be knocked off with a hammer, leaving the copper considerably pure. This process lasts about 30 hours.

The silver, now transferred to the lead, is afterwards refined in the usual manner.

The process of *eliquation*, though highly ingenious, is expensive and difficult to conduct, and requires a large supply of lead. To perform it economically, it also requires a copper holding a pretty exact proportion of silver, that is, from $\frac{3}{4}$ to $\frac{1}{2}$ per cent. of silver, neither more nor less, and hence, where there are parcels of copper of greater or less richness in silver, much judgment is exercised in mixing them in such proportions as to allow of *eliquation* with the least expense.

Enamelling

ENAMELLING. The art of enamelling is of great antiquity, but of unknown origin. That it was practised by the Egyptians is evident, from the remains that have been observed on the ornamental envelopes of mummies. From them it probably passed to the Greeks, and afterwards to the Romans, who appear to have introduced the art into this country; as various Roman antiquities have been dug up in different parts of Britain, in which enamels have formed portions of the ornaments. That the Britons received the art from their conquerors may be conjectured from the circumstance of enamelled trinkets having been found in British barrows. That the Saxons practised it is certain, from the jewel found at Athelney in Somersetshire, and now preserved at Oxford; which jewel, as appears by the inscription, was made by command of the great Alfred. The gold cup, given by king John to the corporation of Lynn in Norfolk, proves that the art was not lost under the Normans; for the sides of that cup are embellished with various figures, whose garments are partly composed of coloured enamels. The tomb of Edward the Confessor in Westminster Abbey, constructed in the reign of Henry III., was also ornamented with enamels, pieces of which still remain. The beautiful crozier of the celebrated William of Wykeham, of the time of Edward III., may be also adduced as exhibiting some curious specimens of the application of this art: and other examples might be pointed out, of its progressive descent to our own age.

It would seem from the above brief review, that anciently enamels were principally applied to the purposes of ornament; but since the invention of clocks and watches, their usefulness has been proportionally increased. For clock and watch dials there is probably no substance that could be substituted, that can equal enamel in permanence and beauty: in several respects, it possesses advantages even over the rich metals of silver and gold. Within the last 30 or 40 years, an *imitative enamel* has been used, and, through the scarcity of real enamel, is now in much demand for clock plates; but it is by no means comparable with its prototype: for, being chiefly composed of flake white, ground up with spirits of turpentine, and afterwards mixed with copal varnish, it will neither assume an equal brilliancy in colour, nor continue unchanged in different climates; on the contrary, the action of the air occasions it to become dingy and yellow. In fact, imitative enamelling is nothing more than a branch of the art of *japanning*; which see.

The processes of enamelling have never been accurately described. The jealousies that exist in all arts in which any thing like a scientific knowledge is wanting, operate to seclusion. The practitioner conceals his information from motives of profit, and the amateur seldom acquires an insight sufficiently minute to enable him to unfold the modes of operation. Whatever may be the defects of the present attempt, it will be found to contain a better account of the practical branches of the art than has before appeared.

Enamels are commonly laid upon a metal ground, yet they have been sometimes used in substance, for dishes, flower-pots, ornamental vessels, figures, vases, &c. In these cases, the enamel is run into moulds immediately from the pots in which it has been melted. The metals employed to enamel on are gold, silver, and copper. Of the other metals, some are too fusible to endure the action of the fire, and the remainder, as platina, &c. are, to use the language of the art, too *strong*, for the enamel: that is, the adhesion between the two substances is not powerful enough to keep them together, the enamel cracking as it grows cold, and flying off the metal in flakes. It appears, therefore, that a certain, however slight, degree of oxydation is necessary to make the enamel and the metal unite with sufficient firmness. Gold is unquestionably the best substance to enamel on, its richness of colour showing a beautiful tinge through the enamel: yet the metal generally used, except for watch-cases, and valuable articles of jewellery, is copper; and that on account of its superior cheapness. Both the gold and the copper should be of the finer kinds, the others being too refractory to agree properly with the enamel.

By the custom of the trade, rather than from any principle of utility, enamelling is now divided into two branches, *viz.* dial-plate enamelling, and transparent enamelling. The former includes the manufacture of clock and watch plates, with fluxed plates for enamel painting, the latter comprehends the enamelling of watch cases, broaches, pins, and other bijoux: of late years the making of these lesser articles has gradually grown into great disuse in this country.

Dial-Plate Enamelling, consists of the two divisions of hard-enamelling, and soft, or glass enamelling; in the first branch, the Venetian enamels only are employed, in the last, the English or glass enamels. The practice of hard-enamelling requires more skill, time, and labour than the others, and is consequently esteemed the most. In preparing the metals to be enamelled on, whether of gold, silver, or copper, the process is similar; one description will therefore suffice for the whole:—and first of the making of watch dials.

The copper being evenly flatted in long slips (which is done at the flattening mills between steel rollers) and to a proper thickness, pieces are cut off for use according to the size wanted. They are then annealed in a clear fire, in order to make them sufficiently pliable to take the required forms which is given to them by means of dies. The dies are small circular plates of brass evenly turned, varying in thickness, perhaps, from the sixteenth of an inch to an eighth, or more, according to their diameter. Some of them are flat, others are hollowed out for the purpose of giving a slight curve to the *copper*, as the metal to be enamelled on is technically termed when prepared for use: the edges of the dies are turned off in an oblique direction, and in the centre is a small hole, rather larger than that which is wanted in the dial-plate. A complete set of dies varies in size from about three-fourths of an inch to two inches and a half, the gradations being very small, perhaps

not more than the thirty-second part of an inch between each.

The copper being cut with a pair of scissars nearly to the size required and properly annealed, is next placed on the die best adapted for the purpose, and the eye, or centre hole, is made. This is effected by first forcing up the copper into the hole of the die with a small round-headed punch; by this means a small concave bulge is formed, the upper side of which is then filed through with a smooth grained file; it is then again placed on the die, and pressed gradually open till it nearly fills the hole with an oval burnisher; it is afterwards pressed tighter into the hole with a round broach, the burr being occasionally taken off by the file, and care employed to prevent the eye from cracking. The punch, burnisher, and round pin, are all of steel; the two latter taper in regular gradation towards the handles.

When the eye is completed, the edge of the copper is cut round, so as to leave a small part, probably about the thirtieth of an inch, projecting beyond the die. The projecting part is then turned up, or burnished, against the edge of the die, the copper being first laid smooth and flat by the burnisher. The turned-up edge of the copper is afterwards filed evenly round, and reduced to the proper height, according to the thickness of the brass-edge, or rim, to which it is to be fixed when in the watch. The inside burr is then scraped off with a graver, and still further cleared away by means of a scratch-brush: this latter tool is composed of small brags or steel wire tied together in a round bundle, about the size of the little finger. The purpose for which the eye of the copper is formed, and the edge turned up, is to retain the enamel in its proper place, so that the plate may be finished both square and neat.

According to the kind of watch to which the dial is to be applied, the copper, if for a seconds watch, must be kept almost flat; or if for a watch where a greater space is wanting beneath, to give more scope for the wheels, must be raised from the edge to the centre in a regular and exact manner. To effect this a small circular block or setting die is used, made of box or other hard wood turned out to the necessary degree of concavity, and having a hole in the middle to receive the eye of the copper when placed within the hollow of the block. The copper is then gradually set up to the convexity or height required by rubbing it gently yet firmly with a bent, or setting spatula, formed of a thin slip of steel, about five inches long, properly fixed. It is now ready to have the feet soldered on, by which it is to be pinned down to the brass edge or frame of the watch; and the places for the feet being marked on the back of the copper, through the holes drilled for the purpose in the edge or frame, the feet are prepared for soldering.

The feet are always of wire of the same kind of metal as that to be enamelled on, and the wire is drawn into different thicknesses, proportioned to the size of the intended dial-plate; thus varying perhaps from the tenth to the sixteenth of an inch. In the more common kinds of enamelling, the feet are generally cut off from silvered wire, that is, copper wire plated with silver; the silver itself forming the solder when the feet and copper are exposed to the united action of the lamp and blow-pipe. In the best kind of work plain copper wire is used, and the feet are fastened to the copper by means of speltre, or of silver solder. When sufficient care is exercised, either of these modes is equally appropriate, but the feet soldered on with speltre take the firmest hold; those with the silvered wire the slightest. The feet are evenly filed, either to a flat face, or an angular one, according to the description of copper for which they are

wanted; and are cut off the wire into proper lengths by a pair of cutting-pliers or nippers. In order to make the feet remain in their places, and facilitate the soldering, the end of each foot, before putting it on the copper (which is done by means of a pair of corn-tongs or tweezers), is dipped into a slight wash of borax and water, through which it adheres with sufficient force to admit of its being exposed to the power of the blow-pipe. The lamp in common use contains from a pint to a quart of oil, and has a cylindrical spout projecting about three inches, and being an inch or more in diameter. This space is filled with cotton, which being lighted, a good strong flame is produced. The copper is carefully placed upon a piece of solid charcoal, long enough to be held in the hand, and the flame being then propelled by the blow-pipe against the solder, or silvered wire, as the case may be, the feet are firmly united to the copper. In this operation, attention must be given to the exact degree of heat required to fuse the solder, for should it be too powerful, the copper itself will melt at the same instant: care must be taken also that all the feet keep in their due places, otherwise the copper will not fit properly, and the feet must either be cut off, and new ones soldered on, or much trouble will be found in drawing the holes of the brass-edges or frames, to get the coppers into their proper central situations.

The copper being thus far advanced is thrown into the pickling-pan, in order to free it from the scale or oxydable covering acquired from the heat. The pickle is either oil of vitriol, sufficiently neutralized for the purpose by water, or else a solution of the best double aquafortis. When the scale is enough softened to admit of its being removed by a soft brush, used with water and a little white sand, the copper is taken out of the pickle, and all the impurities being washed away, it is dried by means of heat, or else with a soft cloth. In this state, the copper will generally require to be again put into a proper shape, by means of the brass die, and setting block, as it is scarcely possible but that some irregularities will be produced through the operations last described. It is also hardened in a slight degree by rubbing the under side with the setting spatula, and the surface with the scratch brush. When this is done, the copper is completed, and fit to be enamelled on. It is to be remarked, that when many coppers are prepared at once, much time is saved by turning off the edges by means of the lathe and arbour, instead of by filing them even in the manner detailed above.

The above are the methods by which the common coppers are prepared; it is now requisite to describe what are called *French edges*, from their having been first made in France. These are of two kinds, the solid French edge and the laid-down French edge. To make the former, a piece of copper is taken, either about a sixteenth or a twelfth of an inch thick, according to the diameter of the intended plate, and a hole being drilled in the centre, the copper is placed upon an arbour, and fixed tightly by means of a small cone and screw-nut fitted to the mandrel. The arbour being then fixed upon a lathe, the edge of the copper is next turned off in an oblique direction, inclining inwards, with a graver, and the copper is then reduced to the proper thickness for enamelling from the edge to the centre, by means of a scraper and other tools; thus leaving the edge solid, and taking care also that a sufficient substance is left unreduced round the cone, to form the outer circle of the eye. The laid-down French edge is made by preparing a copper in the common way from a thin slip, the edge being left rather higher than usual, and then fixing it upon the arbour, when the edge of the copper being first turned perfectly even with a

graver, is next forcibly bent inwards by a small triangular tool, (perhaps formed from the end of a three-square file worn smooth,) and afterwards squared and finished by the graver and scratch-brush. It is in general necessary to reverse the coppers on the arbour, and turn a small portion of the under side away, both of the solid and laid-down kinds, in order to make the edge of a due sharpness. The coppers are lastly set up, and the feet soldered on, as before described. French edges are mostly used for watches of a particular kind, where room is wanting, and the dials are fixed upon the frames without a brass-edge.

When a dial is made for a seconds' watch, or for one requiring still more circles than two, the additional eye, or eyes, is made by marking the centres accurately with a point on the under side of the copper, and then bulging the copper upwards with a small punch from each centre, by striking it gently with a small hammer into a piece of lead, about three times the thickness of a die; the lead forms a sufficient resistance to prevent the eye from cracking, and is yet soft enough to admit of the copper being bulged up evenly. The small eyes are afterwards evened with the file, and opened with a small needle or round-pin to the required sizes. Some trivial variations in the mode of making the seconds' holes, &c. occasionally occur.

The coppers being thus prepared, the next process is that of *enamelling*, properly so called. Where the operations of *hard* enamelling, and *glass* enamelling, are dissimilar, the difference will be described in proceeding, but to a certain extent they are the same.

The enamel, as it comes from the makers, is generally in small cakes from four to five or six inches in diameter. In preparing it for use, a small hammer is used, having one end flat, and the other of the shape commonly employed to rivet with. With this the enamel is broken into thin pieces or flakes, by striking the edge of the cake smartly as it rests upon the fore finger of the left-hand. The pieces are then put into an agate mortar, and with a pestle of the same kind are finely pulverized, the splinters being prevented from flying about, by keeping the enamel covered with pure water all the time the process of *grinding* is going on. The point at which the trituration should be discontinued, can only be ascertained from experience, as the different kinds of enamel, and the different modes of its application, require the *ground enamel* to be either more or less fine. In general it may be stated, that the *backing* should be much finer than the *first coat*; the *second coat* of an intermediate fineness; the hard enamels considerably finer than the glass, and the flux still finer than those, as the fire operates with less effect upon the flux than upon either of the former substances. In grinding, great care must be taken to keep the enamel free from dirt, and the light flux which arises must be washed away three, four, or more times, as may be necessary in the course of the operation, till the water comes off quite clear. A small tea-pot is commonly used to pour the water from, and when the enamel is ground sufficiently, the produce is emptied into some other small cup for use, the surface being kept just covered with water.

The manner in which the grinding is performed, is by placing the mortar upon the work-board, on a coarse piece of flannel or linen, twice or thrice doubled, and wetted to prevent its slipping. The handle of the pestle is then grasped firmly about the middle with one hand, and the palm of the other being placed upon the top, the operator inclines the upper part of his body over the mortar, and crushes the enamel by pressing forcibly with his breast upon that hand which covers the pestle. This motion is repeated in quick succession, till all the larger pieces are reduced into

coarse and uneven grains; which grains are afterwards ground to the requisite equality and fineness, by holding the mortar firmly down with one hand, and with the other giving a circular direction to the pestle, using at the same time as much strength as can be conveniently exerted.

In enamelling watch dials, many coppers are usually prepared to go on with at once; that method possessing the three-fold advantage of saving time, materials, and labour. When the enamel is ground, therefore, the coppers having been first cleaned by the pickle, and carefully brushed out with water, are spread, face downwards, over a soft half-worn cloth, or smooth napkin, and a thin layer of hard enamel, called, in its ground state, the *backing*, is spread over the under sides with the end of a quill, properly cut, or with a small bone spoon. The coppers are then slightly pressed on by another soft cloth or napkin, which, by imbibing some portion of the water, renders the enamel sufficiently dry to be smoothly and evenly spread with the rounded side of a steel spatula. The water is then again dried out by the napkin, and a yet further evenness produced by going over the enamel as before, with the spatula, and these operations are repeated, till the back becomes completely smooth, and the enamel is of an equal thickness all over. It must be observed, that the water should not be *entirely* absorbed, as in that case the enamel would fall off, in powder, before the subsequent operations are completed. When the enamel is properly spread, the loose particles are carefully cleared away from the edge and eye of the coppers; from the former by the spatula, from the latter by twirling round it the pointed end of a quill, and the process of *laying the bottoms* is thus finished. Some slight variations to the above method are in use among different artists, but the difference is scarcely important enough to require description. In some instances the enamel is laid on with the spatula itself, and the coppers, instead of being held between the fingers, are placed upon the round pin, by means of the centre holes, till the backs are duly spread: in both modes due care must be taken that the coppers are not bent out of their proper forms.

The next operation is to lay the *first coats*; that is, to spread a layer of *glass* enamel over the upper sides of the coppers. In doing this, the surface is first brushed slightly over with a small camel-hair brush, or a hare's foot, to remove any dirt or extraneous particles of enamel, as the mixture of any hard enamel with the glass would infallibly spoil the work. The glass is then spread upon the coppers in a layer, the thickness of which is commonly the same as the height of the edge and eye. The water is afterwards slightly absorbed with a clean napkin smoothly folded, and the enamel spread by a thin, flat spatula, till all unevenness is removed, and the surface lies regularly from edge to centre. The edge being then gently tapped twice or thrice at different places with the spatula, the water rises towards the top, and is again dried off by the napkin, when the enamel is once more made smooth by the spatula, and the water being wholly taken up by the napkin, or as nearly so as can be effected, without disturbing the enamel, the *first coats* are placed upon rings for *firing*.

The rings used in enamelling are generally made of a mixture of pipe-maker's clay and Stourbridge clay, rolled up into the form of cylinders, and turned in a lathe by means of a cylindrical piece of wood forced through the centre of the mass when wet. Each ring is about a quarter of an inch in thickness, and the same in depth; the upper side is prepared for use by rendering it slightly concave, which is done by rubbing it carefully upon a half-globe of lead sprinkled over with fine silver sand: the under side is nearly flat. Through the concavity thus given to the rings,

the edge of the copper or dial-plate only is suffered to touch, by which means the enamel on the back remains undisturbed, and the edges are prevented from flicking by rubbing over the surfaces of the rings with soft chalk or whiting.

The first coats having been placed carefully upon the rings, are next put into a shallow tin vessel, called a tin cover, which is either made square or round, according to the fancy of the artificer, and is commonly about three quarters of an inch in depth. All the moisture is then slowly evaporated from the enamel, by placing the cover upon a German stove, or in some other convenient situation near a fire, where the evaporation can be properly regulated; for, should the water be dried off too quickly, the work would be in danger of spoiling from *blebs* or *blisters*. These are very small air-bubbles, which, by rising to the surface of the dial-plates, destroy their smoothness and beauty. They appear to be occasioned, partly by want of due care in laying on the enamel, and partly by the confinement of the air which the water contained, and which, in the process of firing, becomes rarefied; throwing off, by its expansion, a portion of the surrounding enamel, yet not entirely escaping without a very vivid heat, and even then resolving into black or green specks, so coloured through the oxydation of the copper.

The *firing* is executed beneath a muffle, placed in a small furnace ignited with coke and charcoal. (See *MUFFLE* and *FURNACE Enamellers*.) The furnace being drawn up to a sufficient heat by means of a regifter, the first coats are taken separately from the tin covers, and placed upon thin planches of clay, or iron, chalked over, and gradually introduced beneath the muffle; where, in a very short time, the enamel melts, or technically *runs*; and becoming properly consolidated, the first coat is complete. Great attention is requisite in this operation, to prevent the enamel from being over-fired; as in that case, the glass would lose some portion of its opacity, and other defects also be produced, to the detriment of the work. The planches are placed towards the further extremity of the muffle, by means of a pair of spring tongs; and as soon as the fusion is seen to take place, are turned carefully round, in order that every part should be equally fired. The planches are generally made circular, and slightly concave, for the convenience of moving the work without danger of shaking off the enamel before it becomes fixed by the heat.

As all solids, when reduced to a granulated state, occupy a greater space than before, *et vice versa*, it will be found that a very considerable depression has been produced in the enamel of the first coats by the act of fusion; and that the edge and eye are now much above the surface. This deficiency in substance it is the office of the *second coats* to supply. When the work is cooled, therefore, the scale is wholly removed from the edges and eyes by means of a fine-grained Lancashire file, or a smooth grey-stone; and being then washed and dried, each plate is put upon a small round wax-block, of sufficient bulk to be held in the hand, and about four or five inches high. The feet are then either pressed firmly into the wax which covers one end of the block, or the plate is otherwise fixed by means of three small cones of wax placed triangular-wise upon the block; care being taken not to strain the enamel by too weighty a pressure. A second layer of ground enamel is then gently spread with a quill, and prepared for firing by the napkin and spatula as before; after which the second coats are placed upon the rings, and the moisture being evaporated in the tin-cover, (one edge of which, both in this and in

the preceding operation, should be left a little open to give issue to the steam,) they are ready for a second fire.

The second firing requires an equally cautious management as the former one. The plates must not be over-fired, nor must the heat be suffered to melt the enamel too rapidly; but a kind of rotatory motion, called *coddling*, must be given to the work, by holding the loaded planch lightly with the tongs, and gently drawing the edge of it towards the mouth of the muffle, and then returning it to its former place, till the fusion be complete; a proper knowledge of which can be gained only from practice. The work is now in a fit state for polishing.

Polishing, in this art, has a twofold signification: it not only means to render bright, according to the common acceptance of the term; but also to make even, without any reference to glossyness. The enamel has a natural brightness of surface acquired from the fire; and when this is removed, it is only necessary again to expose it to a due heat, to cause it to reassume its former character. Yet as this brightness exists independent of evenness, and as evenness is essential to the perfection of enamelling, it is requisite, in most cases, to produce that quality by the methods next to be described.

The materials used in polishing glass plates are grey-stones, rag-stones, sometimes called burrs, fine ground silver sand, and water. The grey-stones ought to be of a fine grain and even texture, without knots, which would be very detrimental by making deep scratches in the enamel; instead of wearing it away evenly. The plates are taken separately, and the thin edges are first worn off by one of the finer grey-stones, till they become smooth and equal; after which the eyes are rubbed down, till the centre of each plate is even and square. Either the grey-stone or the rag-stone is next employed, according to the nature of the work, to wear away all the irregularities that may exist on the surface of the enamel; the rag-stones being only used for the more common kinds of dials. This is done in different ways; *viz.* first, either by holding the plate upon the fore and middle finger of one hand, and giving it a sort of circular motion by means of the thumb, whilst with the other hand the polishing-stone is rubbed with a forward and backward stroke over every part of the surface; secondly, by holding the polishing-stone on the work-board with one hand, and with the other rubbing upon it the face of the enamel; or, thirdly, by fixing the plate upon a cork, either by means of the feet, or with a piece of wet flannel, and with the fingers giving it a kind of rotatory motion, whilst the polishing-stone is rubbed over it in a similar manner. The ground silver sand is used to give sharpness to the polishing-stones, and wear away the enamel with greater celerity than would be otherwise acquired; and the act of polishing is continued till all the gloss is ground off the surface. In this operation great care must be taken that the pressure be not too powerful, as the plates will then crack in the fire, and can never, or very rarely, be properly mended.

When the enamel is sufficiently polished, which is easily known by the criterion of all the gloss being removed, the plates must be clean washed, and the specks of dirt, &c. picked out with a sharp graver. They are then well rubbed over with some fine ground glass, either by means of a cloth, a glass mull, or perhaps a small bit of fir-wood cut smooth, in order to remove the stains that may be left by the polishing-stones; and the clean water being suffered to run over them, they are wiped dry, and again placed upon the rings for firing.

The degree of heat necessary for polished plates is determined by the finer or coarser modes in which they were prepared; as the fusion is much facilitated by the enamel being free from scratches. When the surface is properly run, that is, when it becomes perfectly smooth, even, and bright, the plate is completed; and when cold, is fit for painting on. See *PAINTING of Clock and Watch Dial-Plates*.

The above description regards more particularly the best kinds of work; but for the more common work there are two other modes of enamelling practised, which it will be requisite briefly to explain. The plates made in these ways are called *run-down plates*, and *run-down second coats*.

Run-down plates are those which are made by laying the enamel upon the coppers in sufficient quantity to form plates of the required thickness, without putting on a second coat. Both labour and fire are thus saved; but that neatness, regularity, and squareness, which are acquired by the first method, are rarely obtainable in this: and indeed flat plates can hardly be managed at all in this mode. Run-down plates require more coddling than any other; and a longer continuance of vivid heat is necessary to make the glass flow to a proper evenness of surface: the plates being wholly completed with one fire, and without polishing. It is obvious that the most common work only can be thus manufactured; for that of the next superior description, the *run-down one coats*, are polished off with the rag-stone, and undergo a second firing. The *run-down second coats* are those which are reduced to a surface comparatively even by the second fire, and are then painted on without being polished off.

In enamelling *hard-plates* for watches, the coppers and the first coats are prepared in the manner above described; excepting perhaps that the layer of glass is rather thinner than in glass-work only. The hard enamel, which is generally most valued as it approaches to a rich cream colour, is broken down, and ground in the same way as the glass, if a small quantity alone be wanted; but if otherwise, it is first broken from the cake with the hammer, and then pounded in a steel mortar, till reduced into coarse grains. These grains are then exposed to the action of a magnet, in order that all the particles of steel that have been broken off the mortar in the act of pounding may be taken away, as they would infallibly spoil the work, by rising in black specks to the surface of the enamel, when in the fire. As an additional precaution, also, it is necessary to put the granulated enamel into a small basin, and pouring upon it a strong solution of oil of vitriol, or aquafortis, to suffer it to stand for some hours, that the steel particles, &c. may be wholly dissolved; after which, the enamel must be very carefully washed, till the water comes off pure and tasteless: for should any of the acid remain, the work would certainly blister. The enamel is then ground to the necessary fineness in an agate mortar, and afterwards spread over the first coat with a quill, in small quantities, and as evenly as it can be laid, that it may require the use of the spatula as little as possible. The water is then partly absorbed by a very fine and clean napkin, and the enamel smoothly spread and closely compressed with the spatula; after which, more water is absorbed, and the spreading is continued till the surface lies true and equal. The plate is then put upon a ring, and properly fired; and is afterwards polished by placing it upon a cork, (the top edge being first taken off with a fine grey-stone,) and wearing away the surface, first, by a very fine-grained Lancashire file, or smooth piece of steel, and silver sand, ground to an almost im-

palpable powder; secondly, by a fine blue-stone and sand; and thirdly, by the blue-stone alone. With the latter a sort of half-polish should be given to the enamel; and the nigher that polish approaches to complete glossyness, the better; as the plate will then be finished in the third fire with a less degree of heat than would be otherwise wanted. In this process, much caution is required to prevent scratches, which cannot be *run up* by the fire without giving the enamel a greater heat than it will well bear. When the polishing is completed, the plate is carefully cleaned with ground enamel; and should there be any specks, they must be picked out with a small and sharp diamond, and the hollows very dextrously filled up with enamel from a quill-point, that they may neither rise above or sink below the common surface, when the plate is again fired: should they actually do so, they must be made smooth with a blue-stone, and the plate must undergo a fourth fire, to render the surface of one uniform texture and glossyness. Hard-enamel dials are always considerably dearer than glass ones, through the greater labour, attention, &c. that are requisite in making them; and the best watches are almost always made up with dials of this kind.

In the polishing off both of glass and hard plates, much address is necessary to prevent a separation between the enamel and the edge of the copper; for if too great a pressure is exercised, or if the grey-stones, which are employed to wear down the copper, are of too rough a grit, the adhesion will be destroyed, and various black indents arise round the edge of the enamel, when the plate is again exposed to the fire. In glass dials, these defects may be sometimes amended; but in hard-enamel dials, scarcely ever.

The operations of *transparent enamelling* are nearly similar to what have been already described in the making of watch dials. As the work is generally of a more minute kind, greater delicacy of handling perhaps is required; and as the enamels are of various colours and descriptions, more cups, vessels, &c. and additional soft cloths or napkins, are wanting to keep them from mixing. Watch cases are commonly enamelled upon gold, as well as most superior articles of the fancy kind; and the surface of the gold is frequently engraved into different figures and compartments, before the enamel is laid on; by which means the work assumes a beautiful variegated appearance through the vitreous coating.

In enamelling the backs and edges of watch-cases, &c. quince-water is frequently used as the medium by which the enamels are laid on; for this possessing a more adhesive and retentive quality than common water, better prevents the enamel from flowing from its proper situations: for where the convexity is considerable, the enamel will of course have a tendency to float towards the lowest part. When enamels of different colours are intended to be employed on the same article, which is frequently the case in ornamental works, small edges or prominent lines are left in the substance of the metal, for the purpose of keeping the enamels separate; and these are polished with the enamel, and reduced with it to a similar equality of surface. Transparent enamels are not unfrequently polished to complete glossyness, without exposing them to an additional fire: in these cases, the work is finished with rotten-stone.

It is sometimes desirable to take off the enamel from a watch-case or trinket, without injuring the metallic part. For this purpose it has been recommended to lay a mixture of common salt, nitre, and alum in powder, upon the enamel requiring to be removed; and afterwards to put it into the furnace: and when the fusion has commenced, to

throw the case, &c. suddenly into water, which causes the enamel to fly off in flakes.

In ornamental transparent work, a very pretty effect is often produced by applying small and very thin pieces of gold or silver, cut or stamped, into different figures, as acorns, oak-leaves, vine-leaves, bunches of grapes, fruits, &c. upon the surface of the first coating of enamel, where they are fixed by the fire; and are afterwards covered over by the second layer, through which they appear with considerable beauty. When any quantity of fancy-works of similar design is wanting, this mode of enamelling is much cheaper to execute than to have the surface of the metal itself engraved into the required forms.

Clock Dial-Plate Enamelling, is far more laborious than the other branches, and requires considerable experience to be properly executed, though the methods of operation are soon explained. The copper, being procured from the flattening mills in thin slips, and of an adequate diameter and thickness, is cut to nearly the required size with a pair of strong scissars, a circle having been first struck with the compasses. If in a soft state, it is then cleaned by the pickle, and having been brushed out with sand on a flat board, is washed and dried for planishing; if otherwise it must be well annealed before it is thrown into the pickle, where it must lie till all the scale is enough softened to be removed by the hand-brush, sand, and water.

Planishing is a very important part of clock-plate enamelling, and too much care cannot be exerted in the process, as the necessary regularity of surface almost wholly depends upon it. In large plates the action of the fire has a very considerable effect, as it causes an expansion in the metal, which, unless properly guarded against, cannot but operate to the imperfection, and perhaps total spoiling of the work. In flattening also, a sort of twist is not unfrequently given to the copper, during its passage through the rollers, that would assuredly cause the plate to become uneven and out of shape, were it not to be removed by planishing and repeated annealings. Another effect produced by the fire, is occasioning the plate to rise, perhaps irregularly, towards the centre, and this can only be checked by counteracting the action which the heat would otherwise generate in the metal by good planishing. To keep a large plate entirely flat is impossible; or at least no means have as yet been discovered through which that aim can be attained. The best way, therefore, to provide against the irregularities which the fire might cause, is to give to the copper, in the course of planishing, a slight and even rise or curve from the edge to the centre; this can either be effected by the use of large brass dies, or by a machine adapted for the purpose.

The machine of which, probably, there is only one in the trade, consists of two principal parts; the one a solid mass of iron, with a concave and polished face, imbedded immovably in a strong oak block, firmly fixed on a foundation of brick-work, and the top edge hooped with a thick iron ring, to prevent splitting; the other, an answering and weighty mass of iron with a convex face, similarly polished, and fixed in an upright frame of timber, but so contrived as to become moveable by means of sliding grooves, a rope, a pulley, and a lever, and so placed as to fall directly upon the mass beneath, in a similar way to the monkey of a pile-driving engine. The diameter both of the hammer and the anvil, as the upper and under masses of iron may be called, for the sake of perspicuity, is about thirteen inches; that size being nearly as large as clock dials are ever made or wanted. The convexity of the hammer is exactly fitted to the concavity of the anvil, and may be described, perhaps, as forming a portion of a circle fifty feet in diameter; and the

centres of both are kept true to each other, and consequently to the regularity of curve, by means of large screws and nuts, which adjust the position of the hammer by altering the perpendicularity of the bars of iron that the grooves act upon. The power of this machine saves much labour in planishing, as well as time; yet as it is insufficient wholly to prepare the coppers, and as the charge of erecting one would be very considerable, it will never, perhaps, come into general use.

In planishing with this machine, it is necessary to be provided with various thin circular pieces of lead, evenly flattened, and adapted in size to the diameters of the coppers to be planished. Without these the stroke given by the hammer would have a very imperfect effect; and the impulse given by the weight of its fall would also be continually weakening the foundation and bed of the anvil.

The coppers prepared for planishing by this machine are taken separately, (the eyes having been previously cut out to a proper size by means of an iron punch, an hammer, and a lead block,) and each one is laid upon a lead of a correspondent diameter, and placed upon the anvil in such a manner that all the centres agree. The hammer, which has been hitherto retained at some height by an iron stay fixed in one of the timbers, and moving on a pivot, is then let fall, three or four times in quick succession, it being each time lifted up to the height of three feet or more, by means of the lever. The hammer is then again fastened by the stay, whilst the copper is turned over on the lead, after which the operation is repeated, and the copper is then taken off, and another laid down till the whole are gone through. The weight of the hammer, and the impetus acquired by its descent, remove most of the unevennesses in the coppers, yet cannot entirely remedy them: a strong and unequal spring will still be felt, and the metal being now rendered hard by the action of the hammer, annealing must again be resorted to, and the coppers must be pickled and cleaned as before. The machine is then used a second time in a similar way; and afterwards a third, a fourth, a fifth, and even a sixth and seventh time, according to the diameters of the coppers, or to the refractoriness of the metals, due care being taken properly to anneal and pickle them between every operation.

The coppers will now be found of a regular shape, and the spring in the metal tolerably uniform; it is essential, however, to the perfection of the plate, that the spring should be entirely uniform from edge to centre, otherwise the plate would warp and cockle in the fire. A kind of intermediate process must therefore be carried on between the taking the coppers from the machine, and before repeating the annealings. This is performed by means of a circular brass die, about a quarter of an inch in thickness, and from fifteen to eighteen inches in diameter, screwed firmly down to a strong oaken block, having three stout legs, placed triangular-wise, and of a sufficient height to use conveniently when the artist is in a standing posture. The die should have the same degree of curve as the machine, otherwise the effect produced by each would occasion a sort of reciprocal counteraction. The coppers, having passed through the machine, are placed in succession upon the die, and a wooden box-hammer (somewhat resembling that used by gold-beaters) with two faces, the one a circle about three inches over, the other cut away on the front edges, so as to leave only a portion about an inch or an inch and a quarter in breadth remaining in the middle, is then taken, and the copper is both rubbed and struck with it till the metal becomes too hard for any further impression to be made, and requires annealing. The circular end is used to strike the

copper with, which is done by short, quick beats of the hammer, the artist working from centre to edge, and communicating the necessary motion and direction to the coppers by means of the fingers of one hand, so extended over the work as to give the requisite command in guiding it: the other end is employed in rubbing the coppers strongly with a backward and forward action, under which they are moved upon the die by the fingers as before. Where the machine is not used, the planishing must then be entirely performed in the way just described, and great care must be taken, that in the rubbing, the coppers be not bent, which would occasion both additional labour, and further annealing. No positive direction can be given as to the number of times that the coppers must be annealed in the course of the planishing; as a general rule, it may be said that the larger the size, the more frequently must the annealings be repeated. For plates of from three to four inches, twice or thrice is commonly enough; from five to eight inches, about four or five times are requisite; for larger sizes, the annealings must be continued till the spring or action in the metal becomes uniform, as already mentioned. This is best determined by the regularity with which the copper will flap or jerk into the curve given by planishing when turned either side uppermost upon the die. When the planishing is completed, the coppers are cut exactly to the sizes required, and having been pickled and cleaned, they are then ready to be enamelled on. After the last annealing, it is best to planish but slightly, that the coppers may be left in a state of comparative softness.

For time-pieces, table clocks, and some others, *round* plates are commonly used, and in these cases it is necessary to have moveable brass dies formed into the curves required. Round plates are those which have a considerable rise in the centre, made by a pretty quick forcing up of the copper into a sort of shoulder about where the circles of the hours come, and afterwards continuing the rise more gradually. The bent spatula and the scratch brush are chiefly employed to set the coppers into these curves, and where the rise is very quick from the edge, the copper is sometimes turned up as in small dials, that the enamel may be the better retained in its place.

The quantity of enamel wanting for clock dials renders the grinding it a very laborious and tedious operation; especially as the hard kind only can be used with complete certainty. It is true that plates of from ten to twelve inches diameter have been made with glass enamel, where particular attention has been given to the *annealing up*, and to the *cooling down*, (phrases that will be presently explained,) and where the backing has been of a quality perfectly agreeing with the nature of the glass. Of the experiments made in this way, however, the success has not always been proportionate to the loss, and the few enamellers who have clock-furnaces cannot always be induced to repeat them.

The enamel for clock dials is broken down in a steel mortar, and afterwards cleaned and ground in an agate mortar, in a similar way to that prepared for watch plates. Sometimes, where the enamel is of a good quality, the *washings* are made use of for backing, and no bad consequence results, but this requires considerable care in the laying on as well as in properly drying, in order to prevent the surface of the back from rising in blisters, either entirely or partially. *Washings* is the name given to the almost impalpable powder which arises in grinding, and floats in the water, intermixed with the dust and minute hairs which are sure to fall into the mortar, and which renders it necessary that the enamel should be several times washed during the process by pouring off the buoyant matter from time to time, and introducing

fresh water, from the tea-pot. Pure spring water ought always to be used, and a large basin provided for the reception of the washings.

In the best and largest kinds of work, the washings ought never to be used, as their great propensity to blister can hardly be counteracted; and when the blistering is considerable, the plates will assuredly *cockle*, or get out of shape. The peculiar fineness of the washings, also, occasions it to be very difficult to lay on as backing in an even manner. Where the enamel in substance only is used, the success of the work is rendered more certain; the additional expence therefore is fully balanced by the greater security.

The general way of putting on the enamel is to lay the copper upon a cloth, twice doubled, and placed upon a die or piece of board, for the convenience of turning. The backing is then spread carefully over it by means of a small ivory or bone spoon, and when the whole surface is covered, the water is partially dried off by another cloth, and the enamel laid even by a large spatula, (see *SPATULA*,) finely polished. These operations are repeated till the back surface is sufficiently evened and dry; when the copper is turned, and the first coat laid on and evened in a similar manner. The work is then placed upon a planch for firing, and is next put into the annealing places in the upper part of the furnace, (see *FURNACE for Clock-Dials*,) where the humidity is gradually evaporated as the fire draws up. The planches are from a quarter of an inch to three quarters in thickness, in proportion to the size, and are either made of fine free-stone, or of a composition of Stourbridge clay, pipe clay, and *old fluff*, as the broken muffles, planches, &c. are called, pounded together in an iron mortar, and passed through a coarse sieve. The face of each planch is either flat or rubbed into a similar curve to that given to the coppers, and before the work is put on to it, a slight covering of whiting, dried, is sifted over it, through a small brass-wired sieve: this is done to prevent the enamel from sticking to the planch when in the act of fusion.

The muffle is *got up* or rendered hot with sea-coal, and when sufficiently vivid, which is known by its near approach to a white heat, the first coats are taken from the annealing holes by means of iron prongs, which are slid beneath the planches by a steady and careful motion, lest the enamel should be shook whilst in powder; to prevent this, also, a farther provision is frequently made by means of *irons*, as they are called in the business, which are placed below the planches, and having a round form, and a convex bottom, are extremely useful in moving the work, by admitting the prongs to be readily passed below them. The irons are adapted to the size of the planches, and are formed out of thin iron plates, and are cut into a circular shape; some portions of the metal, to render the irons less weighty, being wholly removed from between the rim and the centre, which from this circumstance appear to be connected by cross bars.

When the first coats are properly fired, which can only be determined from practice, they are replaced in the annealing holes, and there left for some hours to cool down, all the fire having been first raked out from the furnace. The operation of cooling down must be effected in a very gradual manner, for were it done too quickly, the plates would crack in different places, through the action of the metal upon the enamel. The particular cause of this cracking seems to arise from the surface of the enamel being too suddenly fixed by the cold air, to admit of that gradual adjustment to the contraction of the metal, which the latter, by retaining the heat longer than the enamel, renders necessary. On a similar principle, the annealing up of the second coats must be equally progressive; for should they be too

suddenly put into the fire, the metal, by expanding with the heat before the fusion of the enamel has commenced, would cause the enamel to fly through its brittleness, and the surface would be thereby streaked with cracks.

The enamel for second coats, as in watch plates, must be ground finer than for first coats, yet not so fine as for backing. It is laid on with a spoon, and reduced to a smooth and equal surface by the spatula, in the same manner as above described; and the plate being enamelled with the requisite attention, is fired a second time, and gradually cooled down as before. The next operation is polishing.

Clock plates are polished by a somewhat different process than watch dials. When perfectly cold they are taken off the planches, and either carefully fixed upon a bed of wet sand, so that not any hollow or vacancy is left below the plate, or imbedded in a similar way with sand upon wet flannel, twice or thrice doubled. When thus prepared, the surface is gradually worn even by means of fine silver sand, passed through a sieve, that the coarser particles may be prevented from scratching the enamel, and polishing-stones formed of flint pebbles, ground at one end to a regular surface. The sand is used with water, and the operation is performed by giving the polishing-stone a quick circular direction in progressive movements over every part of the plate, till the surface is evenly reduced, which is known by the glossyness being wholly worn off: this occupies from half an hour to an hour, or more, according to the size and previous evenness of the plate. Sometimes the polishing is accelerated by using pieces of lead or iron, as half-pound weights, for instance, in the early stage of the process, and afterwards finishing with the flint; and that not only to give a smooth surface to the enamel, but likewise to remove the general stain or blackness which proceeds from the use of the lead or iron. When the polishing is completed, the plates are well washed and brushed, and afterwards made perfectly clean by some fine enamel being ground over the face of each with a small mull or polishing-stone for about a quarter or half a minute; the operation being repeated twice or thrice, as may be necessary, and the loose enamel being carefully wiped off with a smooth cloth or napkin, after the last cleansing, instead of being washed away: this is done in order that the small pores which are sometimes laid open by polishing into the substance of the plate, may be filled up by the minute particles of enamel that escape the action of the cloth, but would be removed by the water. Whatever specks or blisters may be in the plate, are then opened with the diamond, and the holes neatly stopped with finely-ground enamel from a quill-point, as in watch-plates; the *stoppings up* being suffered to lie rather higher than the surface, to admit of the reduction in bulk occasioned by the fusion. The plates are now again put into the annealing places upon the planches; and the furnace being properly heated, are fired for the third and last time, before painting. In this latter firing, great care should be taken that the enamel be not over-fired, which would occasion a freckled appearance in the plate, when held against the light; and if the work is drawn out from the muffle after the fusion has commenced, and again returned to complete it, the air will be found to have given additional richness to the glossyness of the surface. The precise time required for firing polished plates can only be known from practice; those on which the finest polishing-sand was used, and, of course, where the scratches are less deep, wanting less heat than when the sand has been employed in a rougher state. After firing, the finished plates are returned to the annealing-holes, and gradually cooled down for painting on. See *PAINTING of Clock and Watch Plates*.

In the making of *fluxed plates* for enamel-painting, similar methods of planishing are practised to those already detailed; and similar or even increased care must be taken in destroying or regulating the spring of the copper. Fluxed plates are commonly either square or oval: in the square ones, about an eighth of an inch, or somewhat more, should be cut off each angle of the copper, previous to enamelling, to prevent the danger of breaking them. In preparing them for the flux, every thing is conducted in the same way as for clock-dials, till they are polished off, when, instead of firing them in their polished state, the flux is laid on as a third coat. In grinding the flux, very particular attention must be given to keep it free from dirt; and the grinding must be continued till the flux becomes extremely fine, as it will not otherwise flow to an even surface, when exposed to the fire, without a more intense heat than the substance will well bear. The flux indeed requires a peculiar delicacy of treatment, and the firing of the fluxed plates must be managed with great caution and nicety. The heat which they require in fusion is much stronger than that for enamels only; but the exact point of time for withdrawing them from the furnace must be dexterously seized, lest the flux should fall into freckles. It is not customary to polish off the flux, as by so doing it would be deprived of some portion of its brilliant richness; yet that perhaps would be in some measure compensated for, by the superior evenness that would be attained. Fluxed plates must be cooled down with great care, as the brittleness of the upper coating renders them more liable to crack when too suddenly made cool. In fluxing, hard enamel must always be used; as the flux will not agree with glass enamel, but cracks in circles as it grows cold. See *FLUX*.

The greater ductility of gold, and its superior mellowness of colour, render it by far the best metal that could be employed for the basis of fluxed plates; though, on account of the expence, it is seldom used. For naked figures, portraits, or other subjects, where much flesh is exhibited, gold plates ought to be exclusively employed, as their rich hue would save considerable labour in the painting.

Till the present age, fluxed plates were seldom made of a larger size than four or five inches; but since the art of enamel-painting has been carried to such great perfection by Mr. Bone, enamel-painter to the king and the prince of Wales, they have been progressively increased in extent for his use, and are now made of every size up to twelve and fourteen inches. The largest ever completed measures eighteen inches by sixteen and a half; and Mr. Bone is now employed in painting it from Titian's famous picture of Bacchus and Ariadne, in the collection of lord Kinaird. See *PAINTING on Enamel*.

In chusing enamels for use, great experience is necessary: indeed the most expert practitioner may be deceived, unless he make the requisite trials by aid of the furnace. Some enamels can only be employed alone; others may be used for the upper coats, but require a stronger kind for the backs; and some can be used only for backing. Should a new sort be proffered for use, experiment alone is the criterion by which its qualities can be determined. In a similar manner, some fluxes will only agree with particular enamels; others must be used separately; and others again must be mixed in grinding, before they can be employed with certainty.

In every branch of enamelling, it is essential that the copper, or other metal employed to enamel on, should be of a proper thickness. Should the metal be too thick, the plates will always crack, either in their second coats, or in their polished state; and should it be too thin, they would

be extremely likely to warp from the too powerful action of the enamel. The due medium can only be ascertained by practice; for even the different kinds of enamel will require a difference in the thickness of the metal.

The proper management of the fire, and the mode by which the muffle is heated, will be explained under the words FURNACE and MUFFLE; it need only be stated here, that the time necessary to *get up* a clock furnace varies from about an hour and a half to two and three

hours, or more, according to the intensity of the draught, the method of stoking, and the quality of the fuel. The work is turned in the muffle by means of spring tongs, so that each part may have a regular and due heat; and it is returned into the annealing places with the prongs. Should many plates be fired at one time, the labour will be found to be very severe, and the heat too powerful; as it carries a flux of blood to the head, and occasions languor and oppression throughout the whole frame.

Engine

ENGINE, in *Mechanics*, a compound machine, consisting of several simple ones, as wheels, screws, levers, or the like, combined together, in order to lift, cast, or sustain a weight, or produce some other considerable effect, so as to save either time or force.

The word is formed of the French *engine*; of the Latin *ingenium*, wit; because of the ingenuity required in the contrivance of engines, to augment the effect of moving powers.

The kinds of engines are innumerable; some for war, as the balista, catapulta, scorpio, aries, &c. others for the arts of peace, as mills, cranes, presses, clocks, watches; engines to drive piles, to bore cannon and water-pipes (see BORING), to raise water, wheel and water-works; to extinguish fire, see FIRE-engine, &c. See HYDROCANISTERIUM. See STEAM-engine, &c. See also INSTRUMENT.

ENGINE for cutting *Wheels*. See CUTTING-Engine.

ENGINE for cutting *Fuses*. See FUSEE-Engine.

ENGINE for ornamenting a *Watch-case*. See ROWS-Engine, or ROSE-Engine.

ENGINE for dividing *Circles, Quadrants, Sextants, and Octants*. It is not our intention in this place to enter into the history of the different methods of dividing astronomical instruments into degrees and their sub-divisions, as successively practised by Tycho Brahe, Hevelius, Dr. Hook, Mr. Abraham Sharp, Olaus Roemer, Mr. Graham, Mr. Jon. Sisson, Mr. Bird, Mr. Ramsden, and Mr. Troughton, without the aid of an engine; but, as we propose to treat the subject at some length under our article GRADUATION of *Astronomical Instruments*, we beg leave to refer the reader to that head for such particulars as relate to the manual

operations performed by the beam-compass and otherwise, which are necessary for graduating all circles and other instruments, that are too large to be graduated by an engine.

Among all the improvements in chronometers and nautical instruments, that owed their origin, during the last century, to the munificent encouragement of the honourable Board of Longitude, there is none that has so much contributed to the interest of navigation, considered as a science, as the engine at present to be described; the facility, and at the same time the accuracy, with which the measuring portion of any nautical instrument, however portable, can now be divided by our best engines, are truly astonishing; the fine dividing strokes, which, in many instances, are scarcely visible to, and not legible by the naked eye, when magnified by a suitable lens, are perceived to be laid down with such perfect equality, as to relative distances, that no one who has not examined the means by which they were effected, can conceive the possibility that the expedition, with which the divisions are made, is equal to the accuracy with which they are measured and marked down. In Mr. Smeaton's paper, read to the Royal Society of London, on Nov. 17, 1785, on the "Graduation of Astronomical Instruments," he mentions an engine, made by Mr. Henry Hindley of York, which indented the edge of any circle in such a way, that a screw with fifteen threads acting at once, would, by means of a micrometer, read off any given number of divisions, so as to answer the purpose of sub-dividing the circle. It does not, however, appear that this engine, though it divided the circles of Hindley's equatorial instruments, was intended or adapted so much for graduating circles as for cutting the teeth of wheels in clock-work. (See CUTTING-Engine.) The year in which it was seen

by Mr. Smeaton was 1741, and, consequently, was in Graham's time, who died in 1751. According to the same author, Mr. Ramsden, in consequence of the reward offered by the Board of Longitude to Mr. Bird, for his method of dividing, in the year 1760, turned his thoughts towards the contrivance of an engine that would divide nautical instruments with sufficient accuracy, without the tediousness of manipulation. Accordingly, considering the nature and properties of the endless screw, and probably contemplating what Hindley had previously done in this way, he completed an engine with an indented plate, or wheel, of thirty inches diameter, which, though it did not completely answer his expectations to their full extent, yet was found very useful for dividing theodolites and such common instruments with great facility. This was effected before the spring of 1768, and, in 1774, a much larger and better engine was produced, with an indented plate of 45 inches diameter, which divided a sextant for Mr. Bird's examination so accurately, that the Board of Longitude, ever ready to remunerate any successful endeavour to promote the lunar method of determining the longitude at sea, did not hesitate to confer an handsome reward on the inventor, but on condition that the said engine might be at the service of the public, and that Mr. Ramsden would publish an explanation of his method of making and using it, which he accordingly did in a quarto pamphlet in the year 1777. The sum of money given to Mr. Ramsden was 615*l.*, of which 300*l.* was considered as a reward for his improvement in the art of dividing instruments by means of his engine, and the remaining 315*l.* was paid in consideration of his making over the property of the said engine to the Commissioners of Longitude, for the good of the public. The description which Mr. Ramsden published, being short and explicit, cannot well be abridged, and the drawings, intended as a guide for other artists to work by, are explanatory of all the parts of the engine, as detached from one another; we have therefore given reduced engravings of all the figures, as they were originally arranged, and propose to copy the description without any other alteration than what the references to our plates required.

Mr. Ramsden's Engine.—"This engine consists of a large wheel of bell-metal, supported on a mahogany stand, having three legs, which are strongly connected together by braces, so as to make it perfectly steady; *fig. 1. Plate VII. of Engines*, is a perfect representation of the body thus united. On each leg of the stand is placed a conical friction-pulley, whereon the dividing-wheel rests: to prevent the wheel from sliding off the friction-pulleys, the bell-metal centre under it turns in a socket on the top of the stand. The circumference of the wheel is ratched or cut, by a method to be hereafter described, into 2160 teeth, in which an endless screw acts. Six revolutions of the screw will move the wheel a space equal to one degree. Now a circle of brass being fixed on the screw-arbor, having its circumference divided into 60 parts, each division will answer to a motion of the wheel of ten seconds; six of them will be equal to a minute, &c. Several different arbors of tempered steel are truly ground into the socket in the centre of the wheel. The upper parts of the arbor, that stand above the plane, are turned of various sizes, to suit the centres of different pieces of work to be divided. When any instrument is to be divided, the centre of it is very exactly fitted to one of these arbors, and the instrument is fixed down to the plane of the dividing wheel, by means of screws, which fit into holes made in the radii of the wheel for that purpose. The instrument being thus fitted on the plane of the wheel, the frame which carries the dividing-point is connected at one

end by finger-screws with the frame which carries the endless screw; while the other end embraces that part of the steel arbor which stands above the instrument to be divided, by an angular notch in a piece of hardened steel; by these means both ends of the frame are kept perfectly steady and free from shake.

The frame carrying the dividing-point, or tracer, is made to slide on the frame which carries the endless screw to any distance from the centre of the wheel, that the radius of the instrument to be divided may require, and may be there fastened by a pair of clamps; and the dividing-point, being connected with the clamps by the double-jointed frame, admits a free and easy motion towards or from the centre, for cutting the divisions without any lateral shake. From what has been said it appears, that an instrument thus fitted on the dividing-wheel may be moved to any angle by the screw and divided micrometer circle on its arbor, and that this angle may be marked on the limb of the instrument with the greatest exactness by the dividing-point, which can only move in a direct line tending to the centre, and is altogether freed from those inconveniences that attend cutting by means of a straight edge. This method of drawing lines will also prevent any error that might arise from an expansion or contraction of the metal, during the time of dividing. The screw-frame is fixed on the top of a conical pillar, which turns freely round its axis, and also moves freely towards or from the centre of the wheel, so that the screw-frame may be entirely guided by the frame which connects it with the centre: by these means any eccentricity of the wheel and the arbor would not produce any error in the dividing; and by a particular contrivance, hereafter described, the screw, when pressed against the teeth of the wheel, always moves parallel to itself; so that a line joining the centre of the arbor and the dividing-point, continued, will always make equal angles with the screw. The rest of the parts are represented in *Plates VIII. and IX. of Engines*, where the figures are numbered in succession from 2 to 14 inclusively, which are more easily referred to than the figures in the original plates. *Fig. 2* is a plan of reduced dimensions, of which *fig. 3* represents a section on the line *II A*. The large wheel, *A*, is 45 inches in diameter, and has 10 radii, each supported by edge bars, as seen in *fig. 3*. These bars and radii are connected by the circular ring *B*, 24 inches in diameter, and 3 deep; and, for greater strength, the whole is cast in one piece in bell-metal. As the whole weight of the wheel, *A*, rests on its ring *B*, the edge-bars are deepest where they join it; and from thence their depth diminishes, both towards the centre and circumference, as seen in the figure. The surface of the wheel, *A*, was worked very even and flat, and its circumference turned true. The ring *C*, of which a section is seen in *fig. 3*, made of fine brass, was fitted very exactly on the circumference of the wheel, and was fastened thereon with screws, which, after being screwed as tight as possible, were well rivetted. The face of a large chuck being turned very true and flat in the lathe, the flattened surface, *A*, of the wheel was fastened against it with hold-fasts; and the two surfaces and circumference of the ring *C*, a hole through the centre, and the plane part round it, together with the lower edge of the ring *B*, were all turned at the same time. *D* is a piece of hard bell-metal, having the hole that receives the steel-arbor made very straight and true. This bell-metal was turned very true on its arbor, and its face, that rests against the wheel, was made very flat, so that the steel-arbor might stand perpendicular to the plane of the wheel; this bell-metal was fastened to the wheel by six steel screws. A brass socket, *Z*, is fastened on the centre of the mahogany stand,

and receives the lower part of the bell-metal piece D, being made to touch the bell-metal in a narrow part near the mouth, to prevent any obliquity of the wheel from bending the arbor: good fitting is by no means necessary here, since any shake in this socket will produce no bad effect, as will appear when the cutting-frame is described. The wheel was then put on its stand, the lower edge of the ring, B, resting on the circumference of the three conical friction-pulleys W, to facilitate its motion round its centre. The axis of one of those pulleys is in a line joining the centre of the wheel and the middle of the endless screw, and the other two placed so as to be at equal distances from each other. F is a block of wood (*fig. 1.*), strongly fastened to one of the legs of the stand; the piece, *g* (*figs. 1 and 12.*), is screwed to the upper side of the block, and has half holes, in which the transverse axis, *b*, (*figs. 1 and 11.*) turns; the half holes are kept together by the screws *i*. The lower extremity of the conical pillar, P, (*figs. 1 and 11.*) terminates in a cylindrical steel pin *k*, which passes through and turns in the transverse axis *b*, and is confined by a check and screw. To the upper end of the said conical pillar is fastened the frame G, (*figs. 5 and 9.*), in which the endless screw turns; the pivots of the screw are formed in the manner of two frustra of cones joined by a cylinder, as represented at X, in *fig. 9.* These pivots are confined between half holes, which press only on the conical parts, but do not touch the cylindrical parts; the half holes are kept together by screws, *a, a*, which may be tightened at any time, to prevent the screw from shaking in the frame. On the screw-arbor is a small wheel of brass, K, having its outside edge divided into 60 parts, and numbered at every 6th division with 1, 2, &c. to 10. The motion of this wheel is shewn by the index, *y*, on the screw-frame G. H represents part of the stand (*fig. 1.*) having a parallel slit in the direction towards the centre of the wheel, large enough to receive the upper part of the conical brass pillar P, which carries the screw and its frame; and as the resistance, when the wheel is moved by the endless screw, is against that side of the slit, H, which is towards the left hand, that side of the slit is faced with brass, and the pillar is pressed against it by a steel spring on the opposite side: thus is the pillar strongly supported laterally, and yet the screw may be easily moved from or against the circumference of the wheel, and the pillar will turn freely on its axis, to take any direction given it by the frame L, lying over the wheel in *fig. 1*, and seen more distinctly in *fig. 13.*

At each corner of the piece I, seen in *fig. 1*, and also detached in *fig. 8*, are as many screws, *n*, of tempered steel with polished conical points: two of them turn in conical holes in the screw-frame, near *o*, *fig. 9*; and the points of the other two turn in holes in the piece Q, *fig. 7*: the small end screws, *p*, are of steel, which, being tightened, prevent the conical pointed screws from unturning, when the frame is moved. The brass frame L, *figs. 1 and 13*, serves to connect the endless screw, its frame, &c. with the centre of the wheel; each arm of this frame is terminated by a steel screw; that may be passed through any of the holes, *q*, in the piece Q, *fig. 7*, as the thickness of the work to be divided on the wheel may require, and are fastened by the finger-nuts *r*, seen in *figs. 1 and 2*. At the other end of this frame is a flat piece of tempered steel *b*, wherein is an angular notch: when the endless screw is pressed against the teeth of the circumference of the wheel, which may be done by turning the finger-screw S, seen in *figs. 1 and 2*, to press against the spring *t*, this notch embraces and presses against the steel arbor *d*. This end of the frame, too, may be raised or depressed, by moving the tri-

angular or prismatic slide *u* (*fig. 14.*), which may be fixed at any height by the four steel screws *v*. The bottom of this slide has a notch *k*, having its plane parallel to the endless screw; and by the point of the arbor *d*, resting in this notch, this end of the frame is prevented from tilting: the screw, S, also is kept fast by the finger-nut *w*, in *fig. 2*.

The teeth on the circumference of the wheel were cut by the following method. Having considered what number of teeth on the circumference would be most convenient, which in this engine is 2160 or 360×6 , I made, says Mr. Ramsden, two screws of the same dimensions of tempered steel, the interval between the threads of which being such as I knew by calculation would come within the limits of what might be turned off the circumference of the wheel; one of these screws, which was intended for ratching or cutting the teeth, was notched across the threads, so that the screw, when pressed against the edge of the wheel and turned round, cut in the manner of a saw. Then having a segment of a circle a little greater than 60° , of about the same radius with the wheel, and its circumference made true from a very fine centre, I described an arch near the edge, and set off the chord of $60'$ on this arch. This segment was substituted for the wheel, and had its edge ratched or indented; and the number of revolutions and parts of the screw head contained within the arch of $60'$ were counted. The radius was corrected in the proportion of 360 revolutions, which ought to have been in $60'$, to the number actually found; and the radius so corrected was taken in a pair of beam compasses: while the wheel was on the lathe, one foot of the compasses was put in the centre, and with the other a circle was described on the ring; then half the depth of the threads of the screw being taken in the dividers, was set from this circle outwards, and another circle was described cutting this point; a hollow was then turned on the edge of the wheel of the same curvature as that of the screw, at the bottom of its threads; the bottom of this hollow was turned to the same radius as the outward one of the two circles before-mentioned.

The wheel was now taken off the lathe, and the bell-metal piece D, *fig. 3*, was again screwed to its place, not to be removed any more. From a very exact centre, a circle was described on the ring C, *fig. 4*, about $\frac{1}{6}$ ths of an inch within where the bottom of the teeth would come; this circle was divided with the greatest possible exactness, first into 5 parts, and each of these again into 3; these parts were then bisected 4 times; i. e. supposing the whole circumference of the wheel to contain 2160 teeth, a fifth part would be 432, a fifteenth part (or 5×3) would be 144, and this last number bisected four times would give 72, 36, 18, and 9 respectively; but as it was apprehended that some inaccuracy would arise from quinquesection and trisection, another circle was described on the same ring, at $\frac{1}{10}$ th of an inch within the former circle, and divided by continual bisections into the portions 2160, 1080, 540, 270, 135, $67\frac{1}{2}$, and $33\frac{1}{2}$; and as the fixed wire, to be described presently, crossed both the circles, it was a check on their agreement at every 135 revolutions, and after ratching at every $33\frac{1}{2}$; but as no sensible difference was perceived in the two circles, the former was chosen for ratching: and as the coincidence of the fixed wire with an intersection would be more exactly determined than with a dot or division, the intersections in both circles were used.

The arms of the frame L, *figs. 1 and 13*, were connected by a thin piece of brass $\frac{1}{2}$ of an inch broad, having a hole of $\frac{1}{4}$ ths of an inch diameter in the middle; across this hole a silver wire was fixed exactly in a line to the centre of the

wheel; the coincidence of this wire with the interfections was examined by a lens of $\frac{7}{8}$ ths of an inch focus, fixed in a tube, that was attached to one of the arms L. Now a handle, or winch, being fixed on the end of the screw-arbor, the division marked 10 on the circle K was set to its index, and, by means of a clamp and adjusting screw for that purpose, the interfection marked 1 on the circle C was set exactly to coincide with the fixed wire; the screw was then carefully pressed against the circumference of the wheel, by turning the finger-screw S; then, the clamp being removed, the screw was turned by its handle just 9 revolutions, till the interfection marked 240, *fig. 4*, came nearly to the wire; the finger-screw S was now turned back, and the dividing screw released from the edge of the wheel, which was here turned back till the interfection marked 2 exactly coincided with the wire; the division 10 on the micrometer circle was then set to its index as before, and the screw pressed against the edge of the wheel by the finger-screw S; then, the clamps being removed, the screw was turned a second 9 revolutions, till the interfection marked 1 nearly coincided with the fixed wire; the screw was again released, and the same operation was repeated till the teeth were faintly marked all round the circumference of the wheel. The impression was made deeper by thus going three times round; after which the wheel was ratched continually round 300 times in the same direction, without disengaging the screw, when the teeth were found sufficiently indented. Now, it is evident, that, if the circumference of the wheel were even a whole tooth or ten minutes space greater than the screw would require, this error would, in the first instance, be reduced to $\frac{1}{240}$ th part of a revolution, or two seconds and a half; and these errors or inequalities of the teeth were equally distributed round the wheel at the distance of 9 teeth from each other; but, as the screw in ratching had continually hold of several teeth at the same time, and as these were constantly changing, the above-mentioned inequalities soon corrected themselves, and the teeth were reduced into a perfect equality.

The piece of brass which carries the wire was now taken away, and the cutting-screw also removed, and replaced by the plane one of the same dimensions; on one end of its arbor was put the micrometer circular plate divided into 60, and numbered at every six divisions, as already stated; and on the other end was placed a ratchet-wheel of 60 teeth, seen in *fig. 6*, which is covered by the hollowed circle *d*, carrying two clicks, that catch upon the opposite sides of the ratchet, when the screw is to be moved forwards. The cylinder S, *figs. 5 and 9*, turns on a strong steel arbor F, seen in *fig. 5*, which passes through, and is firmly screwed to the piece Y; this piece, for greater firmness, is attached to the screw frame G by the braces *v*: a spiral groove or thread is cut on the outside of the cylinder S, which serves both for holding the string, and also for giving motion to the lever J on its centre, *figs. 9 and 10*, by means of a steel tooth *n* that works between the threads of the spiral. To the lever is attached a strong steel pin *m*, *fig. 10*, on which a brass socket *r* turns: this socket passes through a slit in the piece *p*, and may be tightened in any part of the slit by the finger-nut *f*: this piece serves to regulate a number of revolutions of the screw for each tread of the treadle R, seen in *fig. 1*. T, in *fig. 1*, is a brass box, containing a spiral spring: a strong gut is fastened and turned three or four times round the circumference of this box; the gut then passes several times round the cylinder S, *figs. 1 and 9*, and from thence down to the treadle R. Now, when the treadle is pressed down, the string pulls the cylinder S round its axis, and the clicks laying hold of the teeth on the ratchet, carry the

screw round with it, till, by the tooth *n* working in the spiral groove, the lever J is brought near the wheel *d*, *fig. 6*, and the cylinder is stopped by the screw-head *x*, *fig. 9*, striking on the top of the lever J; at the same time the spring is wound up by the other end of the gut passing round the box T, *fig. 1*. Now, when the foot is taken from the treadle, the spring in the box unbending itself, pulls back the cylinder, the clicks leaving the ratchet and attached screw at rest till the piece *t* strikes on the end of the piece *p*, *fig. 10*; and the number of revolutions of the screw at each tread is limited by the number of revolutions that the cylinder is allowed to turn back before the stop strikes on the piece *p*. When the endless screw is moved round its axis with a considerable velocity, it will continue that motion a little after the cylinder S is stopped; to prevent which angular motion, the angular lever *n* was made, that when the lever J comes near to stop the screw *x*, it, by a small chamfre, presses down the piece *x* of the angular lever; this brings the other end *n* of the same lever forwards, and stops the endless screw by the steel pin *u* striking on its top; the foot of the lever is again raised by a small spring pressing on the brace *v*.

Two clamps D, *fig. 13*, connected by the piece *a*, *fig. 1*, slide, one on each arm of the frame L, and may be fixed at pleasure by the four finger-screws *i*, which press against steel springs, to avoid spoiling the arms; the piece *q*, *fig. 13*, is made to turn without shake between the two conical pointed screws *f, f*, set fast by the finger-nuts N, N. The piece M is made to turn on the piece *q*, by the conical pointed screws resting in the hollow centres *e, e*. As there is frequent occasion to cut divisions on inclined planes, for that purpose the piece *γ*, in which the tracer or dividing point is fixed, has a conical axis at each end, which turn in half holes; so that when the tracer is set to any inclination, it may be fixed there, by tightening the steel screws *ββ*.

Subsequently to the time of Mr. Ramsden's dividing engine being constructed, Mr. Edward Troughton constructed one to answer the same purpose, which it does in the most perfect manner; and it was our intention to have described it also in this place, but on application to him for permission to inspect its parts and manner of operating, we were sorry to learn that he has pledged himself to give an account of it himself in another work.

ENGINE (by Ramsden) for cutting the Screws of the circular Dividing-Engine.—We mean not to enter here into the history of the screw-engine, as it may be, and has been applied to various purposes, but to describe the engine made and used by Mr. Ramsden for making the individual screws which he used for ratching his engine for dividing circles, &c., and for measuring the angular distance on his circle when ratched. This apparatus, indeed, may be considered as an appendage to the other, and therefore ought to be introduced in this place. *Fig. 1. of Plate X. of Engines*, represents this engine as seen from one side of reduced dimensions; and *fig. 2*, the same as seen from above, of the same dimensions. A represents a triangular bar of steel, to which the triangular holes in the pieces B and C are accurately fitted, and may be fixed on any part of the bar by the screw D. E is a piece of steel whereon the screw is intended to be cut, which, after being hardened and tempered, has its pivots turned in the form of two frustra of cones, as represented in the drawings of the dividing-engine. These pivots were very exactly fitted to the half-holes F and T, which were kept together by the screws Z. H represents a screw of untempered steel, having a pivot I, which turns in the hole K. At the other end of the screw is a hollow centre, which

receives the hardened conical point of the steel pin M. When this point is sufficiently pressed against the screw, to prevent its shaking, the steel pin may be fixed by tightening the screws Y. N is a cylindrical nut, moveable on the screw H, which, to prevent any shake, may be tightened by the screws O. This nut is connected with the saddle-piece P, by means of the intermediate universal joint W, through which the arbor of the screw H passes. A front view of this piece, with a section across the screw-arbor, is represented at X, *fig. 3*. This joint is connected with the nut by means of two steel slips S, which turn on pins between the cheeks T, on the nut N. The other end of these slips S turn in like manner on pins *a*. One axis of this joint, turns in a hole in the cock *b*, which is fixed to the saddle-piece, and the other turns in a hole *d*, made for that purpose in the same piece on which the cock *b* is fixed. By these means, when the screw is turned round, the saddle-piece will slide uniformly along the triangular bar A. K is a small triangular bar of well-tempered steel, which slides in a groove of the same form on the saddle-piece P. The point of this bar or cutter is formed to the shape of the thread intended to be cut on the endless screw. When the cutter is to take proper hold of the intended screw, it may be fixed by tightening the screw *e*, which presses the two pieces of brads G upon it. Having measured the circumference of the dividing-wheel, it was found to require about one thread in a hundred, coarser than the guide-screw H. The wheels on the guide-screw arbor H, and that on the steel arbor E, on which the screw was to be cut, were proportioned to each other to produce that effect, by giving the wheel L 198 teeth, and the wheel Q 200. These wheels communicated with each other by means of the intermediate wheel R, which also served to give the threads on the two screws the same direction. The saddle-piece P is confined on the bar A by means of the pieces *g*, and may be made to slide with a proper degree of tightness by the screws *n*.

ENGINE for cutting the Screw of Ramsden's Engine for dividing Straight Lines.—The exactness of the straight line engine, as made by Ramsden, depends very much on the correctness of the endless screw, which requires some properties that are not absolutely necessary in the endless screw for the circular engine. In that, as there are but a few threads of the endless screw engaged in the teeth of the wheel, it required only that those threads should have a similar inclination to the axis of the screw all round; but in the straight-line engine, where the whole length of the screw is engaged in the moveable plate, it is necessary that the distances also between the threads should be precisely the same throughout the whole length of the screw: as this is effected in a manner in some respects different from the mode of cutting the screw we have just described, we shall subjoin it here, that the reader may take a comparative view of the two methods adopted by that great artist Ramsden. In *fig. 1*, of *Plate XI*, of *Engines*, is a plan of the engine for cutting the screw for dividing straight lines; and in *fig. 2*, is an elevation of the same. The section, as given in the original account published in 1779, does not seem to be necessary for explaining the engine, and is therefore omitted in our account. A, in *fig. 1*, represents a strong circular plate of brass, having its edge ratched, as described in our account of the circular dividing-engine; on its centre is firmly fixed the pulley B by four screws, having a groove turned on its cylindrical part, perfectly concentric with the plate A. C, in *fig. 2*, is a steel axis two feet long, terminating in a point, whereon it rests; the upper part of the axis being firmly screwed to the plate A, and turning in the collar D.

E represents an endless screw, *fig. 1*, which being turned on its horizontal axis, moves the circular plate A round its centre: F is a circular divided small plate, or micrometer-head, which may be turned with or without the endless screw; and on the other end of this screw-arbor is a large pinion *a*, with levelled teeth on its edge, together with the winch X to turn it by. G, seen in both figures, is a triangular bar of steel, which passes over the circular plate A, and is firmly screwed to the frame of the engine at H, *fig. 1*, and I, *fig. 2*. K is a piece of steel forming the arbor of the screw intended to be cut, having a wheel L, on one end acting with the pinion *a* before-mentioned. M and N, *fig. 1*, are two strong pieces of brass, in which the arbor just mentioned turns, and are firmly fixed to the triangular bar G, by means of the screws *n*, *n*, seen at I, in *fig. 2*. O, seen in both figures, is a piece of brass that slides on the triangular bar G, the two extremities of which are made exactly to fit the bar; it slides regularly thereon, and is prevented from rising by the two spring pieces *c*, *c*; near one end of the piece O is an angular groove *q*, *fig. 1*, that holds the tool by which the threads are cut, and is pointed with a diamond, in order to cut the steel after it is hardened and tempered: the cock *w* serves to fasten the tool, which may be set to take proper hold on the steel by turning the finger-screw *s*, and is fixed there by the screw *v*.

To make a perfect screw, it is only required to give the point that cuts the threads an uniform motion parallel to itself, and also to the axis of the intended screw, and that this motion be proportioned to the revolutions of the intended screw as the number of threads may require. To effect this, a piece of thin tempered steel *t*, exactly of the same thickness throughout, is fastened to the slide O at *r*; the other end of the spring being fastened to the pulley B in the groove: now while the circle A, with the pulley, is turned round its centre by turning the endless screw to the right hand, the spring *t* draws the slider O, with the attached cutter *q*, along the triangular bar; at the same time the steel-arbor K of the screw to be cut revolves by means of the communication of its wheel L with the revolving pinion *a*.

The screw, E, of the circular plate has 20 threads per inch, therefore if the number of teeth on the pinion, *a*, be to the number in the wheel L, as the number of teeth on the circular plate, A, is to the number of 20ths of an inch round the circumference of the pulley B, allowing for part of the thickness at the spring *t*, the spaces between each of the threads of the screw to be cut will be also 20ths of an inch. The size of the pulley, B, was determined thus: the endless screw, E, being disengaged from the circular plate A, the slider, O, was drawn back till the end of it came nearly to the piece M; the endless screw was again engaged in the plate A; then having two very small dots on the slider O, set off parallel to one side, at exactly five inches distance from each other, the slider was moved by turning the endless screw E, till one of its dots was bisected by a small silver wire fixed across a hole made in a thin piece of brass fast to the piece N; then O on the micrometer head, F, being put to the index without moving the screw, the pulley was tried and reduced, till just 600 revolutions of the endless screw, E, brought the second dot to be exactly bisected by the fixed wire. These bisections were examined by a lens of half an inch focus, set in a small brass tube, that was fixed perpendicularly over the wire.

ENGINE for dividing Straight Lines, by Ramsden.—When Mr. Ramsden had succeeded in dividing sextants, &c. by his circular dividing engine, and was rewarded by the honourable Board of Longitude, he turned his mind to-

wards the contrivance of an engine that would divide straight lines into any number of assignable parts, and that might be useful in laying down with extreme accuracy the lines of fines, tangents, secants, &c. on sectors and plane scales. The project was realized, and the account was ordered to be published by the Board of Longitude, in the year 1779. We do not find, however, that the original model, which we come now to describe, has been found desirable to copy by succeeding mathematical instrument makers: more simple and less expensive means have been adopted, which are found to answer practically as good a purpose. A beam-compass, aided by proper tables, is quite accurate enough for the nicest purposes of dividing unequal, as well as equal, divisions by bisection; and a pattern once carefully laid down can be used, for transferring the divisions on the common cases of instruments, with greater facility than the engine itself can be worked; and, provided great care be taken to prevent the parallax of the transferring point, the accuracy will be sufficient for all ordinary uses. This engine, which professes to divide any line without an error of $\frac{1}{2000}$ th of an inch, has its principal parts represented in *Plate XII. of Engines*; where *fig. 1*, represents a plan of the dividing portion, as seen from above; *fig. 2*, an elevation of the same seen across; and *fig. 3*, the under side of *fig. 1*, when turned up. The original account contains some sections, which are more useful for the workmen as patterns, than for a general description, which may dispense with them altogether. A, in *fig. 1*, is a strong brass plate, 27 inches long, 4 broad, and $\frac{1}{8}$ th thick; worked exceedingly flat, and of the same thickness throughout, with its two edges parallel. One of these edges is ratched, or cut into teeth, of which there are just 20 in an inch, and is moved by an endless screw, containing just 20 threads in an inch, which actuates the teeth. (See *ENGINE for cutting the Screw of Ramsden's straight-line Engine*.) Each revolution of the endless screw round its axis will move the plate $\frac{1}{20}$ th of an inch along an iron frame, hereafter to be described. A micrometer head is fixed at one end of the screw arbor, divided into 50 divisions, which, by means of a vernier subdividing into 5 parts, measures $\frac{1}{1000}$ th of an inch along the frame. Any rule or other instrument may be fastened on this plate, and may have a line drawn on it divided by a point or tracer, fixed in a proper frame, whereby it has a rectilinear motion without any lateral shake. When lines are to be divided by divisions not commensurable with English inches, which constitute the scale, the line to be divided may be laid down, not parallel to the plate A; but obliquely, so as to make an angle with it, or become the hypotenuse line of a right-angled triangle; which line, by calculation, shall be to the base as the denomination of measure, when longer, is to the English inch; that is, as the secant is to the radius of the triangle, provided the tracer draws lines at right angles to the side of the plate; but if the traced lines be at right angles to the line to be divided, then the divisions on that line will be shorter than they would be on a parallel line of the plate, and in the proportion of the co-sine of the angle of inclination to radius. In order to adjust the inclination of a ruler laid on the plate A, two sectoral portions of a circle are laid down on one of its ends, with an extent from the point J, near the fixing screws on the edge of this plate. The outer sector is divided into proper degrees, and is numbered from 1 to 9, which degrees are subdivided into 6, or 10 minutes spaces; but the inner sector is divided into the proportion of the co-sines to radius 10,000, and its divisions are numbered 10, 20, 30, &c. to 140. The use of this contrivance will be best understood by an example: for instance, if a line of

$9\frac{22}{100}$ were to be divided into the same number of divisions, and in the same manner as if it were 10 inches long exactly; put the ruler to be divided to the cutting frame, hereafter described, and turn the handle, T, that moves the apparatus, till the same edge of the ruler cuts the central point J, and the first division from the O of the inner sector; then screw the ruler fast to the plate A, and when it has moved ten inches in its own direction, the whole length of the divisions on the line divided will be only $9\frac{22}{100}$ inches, though the divided spaces will be respectively equal among themselves. It is not necessary for us to particularize the precautions taken, in making all the spaces of the teeth ratched equal to each other, during the act of ratching, which was done with a notched screw: this was done by means of points previously made and examined, with a wire at every 16 revolutions of the screw, till the teeth were a little indented to guide the screw along the whole line by continual revolutions, as was the case in the circular dividing instrument, more particularly described, because found more particularly useful. B, in *fig. 1*, is a strong iron frame, 48 inches long, having two edges, *a* and *b*, rising half an inch above its surface; these two edges are made very straight, and are in the same plane; the inside of the edge *a* is also made as straight as possible. The plate, A, slides on the two edges of the iron frame; beneath it are two springs, *c*, *c*, seen in *fig. 3*, each fastened at the extreme ends to the plate A, by the screws, *s*, *s*; at the other end of each spring is a roller, *e*, of tempered steel, turning on an axis in these springs; there is also a third roller, *d*, of tempered steel, let into the iron frame, not seen, near where the threads of the endless screw act; this roller has a long axis, so situated that it may be raised or depressed as occasion may require, to bear the weight of the plate A, and rule or instrument placed on it. C, in *figs. 1* and *2*, is the endless screw of tempered steel, with pivots of two frustra of inverted cones, similar to those described in the engine for dividing circles, &c. which turn in adjustable half holes in brass cocks screwed to the iron frame. G, G, in *fig. 3*, are two small steel frames turning on centres, *h*, fastened to the underside of the plate A, and equidistant from the edge of it; in each frame is a roller, *y*, of tempered steel, turning very concentric with their pivots, and exactly of the same diameter. The two small frames are connected together by the long brass bar E, which turns on a stud in each frame, and which preserves its parallelism, on the principle of a common parallel ruler. This apparatus serves to press the edge of the plate, A, with a motion parallel to itself against the threads of the endless screw. On the end of the plate, A, is a spring of tempered steel, acting as a bent lever. The spring end of this lever has a ketch which passes under the head of the stud *l*, that is on the end of the connecting piece E. While the other end of the lever is pressed gradually down towards the plate A, by turning the finger-screw F, the connecting piece, E, is drawn forward, so that the steel rollers, borne by the springs T, in *fig. 3*, pressing against the edge, *a*, of the iron frame, in *fig. 1*, may force the side of the plate against the endless screw.

Besides the micrometer head, already named, the arbor of the dividing screw, which has its threads similar to those of the notched ratching screw, has at its opposite end two sets of ratched wheels; one set for turning the screw, and the other set for stopping it at the proper times. These sets are each composed of three wheels, of which one has 32 teeth, another 48, and the third 50, which afford the means of subdividing the inch into spaces of different denominations; those wheels used in stopping the screw are ratched, with the teeth pointing in a contrary direction to

those of the wheels for putting it in motion. I represents a cylinder of brass, having on one end two steel-rings, *a* and *b*, with their contiguous edges cut into ratched teeth, in contrary directions, so as to fit each other as seen in the figure; on one of these rings is an index, and the other has its teeth numbered 10, 20, &c. up to 50; the other end of the cylinder is made hollow, and contains one of the sets of ratched wheels, already named. There are two slits opposite each other, pierced through the hollow part of the cylinder W; in each of which slits is a click turning on an axis, and pressed into the teeth of the ratched wheel by a small spring; these clicks may be moved along their axis, so as to catch in any one of the three ratched wheels, and may be fastened at that place by a small tightening screw *s*. The cylinder I, with the clicks, &c. turns on a steel axis, attached to the piece K, in a line with the axis of the endless screw. Motion is given to this cylinder round its axis by a piece of catgut, which hath one end fastened to the ratched ring *b*; and the other end, after passing four or five times round the cylinder, is fastened to a treadle, and, on pressing the treadle down, the clicks, *s*, catch in the teeth of one of the ratched wheels; by which contrivance the cylinder I, together with the endless screw, is turned round its axis, and its motion carries the plate, A, along the iron frame, and at the same time winds up the spiral spring *u*; but on releasing the treadle, the said spring unbends itself, the clicks quit the ratched wheel, and leave the endless screw at rest, whilst the cylinder, I, turns in an opposite direction, and raises the treadle to its former situation. V, in fig. 2, is a small square bar of steel, having both its extremities cylindrical; these cylinders move in holes lined with hardened steel, one in the piece D, and the other in the piece K. This bar carries three different pieces, which are of tempered steel; the middle one, *t*, is made to lie in the interval between the threads of the screw cut on the cylinder, and passes nearly half round its circumference: it is kept in the threads by a spring, *e*, that presses on a piece, *q*, screwed to the iron frame; this piece being attached to the bar, V, by a screw, turning the cylinder, I, on its axis, will give a longitudinal motion to the bar V. The upper end of the piece *j*, fig. 2, is formed into a hook, and may be set to catch in the teeth of any of the ratchet wheels, and then be fastened to the bar, V, by a screw *i*; towards the other end of the bar is a piece *j*, which serves to stop the cylinder in turning back, so as to limit the number of revolutions and parts of a revolution required, and is fastened to any required place on the bar, V, by the finger-screw *s*.

When the engine is used, the treadle is pressed down, and the catgut turns the cylinder I; in the mean time, the piece, *t*, moves along the thread till a stud, *r*, on the cylinder, striking on the top of the curved piece *t*, bends the spring *e*, until that piece rests on the piece *q*; by bending this spring, the square bar is turned a little on its axis, and pulls the hook, *j*, into the teeth on the ratched wheel R: then the treadle being released, the spiral spring turns back the cylinder till the piece, *j*, is brought under the stop on the ratchet ring *b*. The parts of a revolution are regulated by setting the number required on the ratchet ring, *b*, to the index on the fixed ring *a*; each of the teeth answers to the motion of $\frac{1}{10}$ th of an inch of the plate A; and the number of revolutions, each of which moves the plate, A, $\frac{1}{2}$ th of an inch, is regulated by setting the piece, *j*, on the bar. I, in fig. 1, represents the steel frame in which the tracer is fixed; this frame turns between the conical points of two screws, *n, n*, of tempered steel, which are screwed in the frame Q, fig. 2; there are also two similar

screws in the same frame Q, at *m, m*; the points of these screws, which are also of tempered steel, turn in conical holes in the piece P; by means of this parallel motion, the tracing point, by which the dividing lines are cut, will always describe the same line without any lateral bending; the tracer is put on the hole in the axis *b*, fig. 1, and is fixed there by the four tightening screws, *f*, that press the holding piece, *c*, against the flattened part of the axis of motion. This small axis, which has its pivots formed of double cones, turns between half holes, and may be fixed when the tracer is set to any required inclination, by tightening the screws of pressure, *s, s, s, s*. Besides these parts of the engine, there is a brass ruler made as an appendage for setting the line to be divided in its true situation, but is not necessary to be particularly described: this ruler may be set parallel to the edge of the plate A, or to any angle of inclination, by turning the handle T, which moves the piece P, with the cutting frame and ruler, on the centre *x*; and the required position may be rendered permanent by tightening the capstan screw *p*.

ENGINE-Shaft, in *Mining*, is generally applied to the shaft or well wherein the pumps are erected for freeing a mine of its water; but in districts where the mines are relieved of water by foughs, as in the mountainous part of Derbyshire, it is common to find the shafts at which they draw ore by a horse-gin, called the engine-shaft, and the gin itself an engine.

ENGINE to draw Fuzes, in *Gunnery*, consists of a wheel with a handle to it, to raise a certain weight, and to let it fall upon the driver, by which the strokes become more equal.

ENGINE to draw Fuzes has a screw fixed upon a three-legged stand, the bottom of which has a ring to place it upon the shell; and at the end of the screw is fixed a hand-screw, by means of a collar, which, being screwed on the fuze, by turning the upper screw, draws out or raises the fuze.

ENGINEER, or **ENGINEER**, in its general sense, is applied to a contriver or maker of any kind of useful engines or machines.

In its more proper sense, it denotes an officer in an army or fortified place, whose business it is to contrive and inspect attacks, defences, works, &c. The term engineer is said to be of modern date, and to have been first used in the year 1650, when one Cap. Thomas Rudd had the title of chief engineer to the king. In 1634 an engineer was called camp-master general, and sometimes engine-master, being always subordinate to the master of the ordnance.

An engineer should be an able and expert mathematician, particularly versed in military architecture and gunnery; being often sent to view and examine the places intended to be attacked; to choose out and shew the general the weakest place; to draw the trenches, assign the places of arms, galleries, lodgments on the counter-scarp and half-moons; conduct the works, saps, mines, &c. and appoint the workmen their nightly task; he is also to make the lines of contravallation; with the redoubts, &c.

Under the establishment of the office of his majesty's ordnance in England, the corps of *royal engineers* consists of one colonel in chief, one colonel in second, three colonels commandant, six colonels, 12 lieutenant-colonels, 27 captains, 28 second-captains, 55 first-lieutenants, 28 second-lieutenants, an inspector-general of fortifications, his deputy brigadier-major, adjutant, and quarter-maller.

The establishment of the corps of *invalid engineers* comprehends a colonel, lieutenant-colonel, captain, captain-lieutenant and captain, first-lieutenant and second-lieutenant.

The corps of *royal engineers* in Ireland consists of a director, colonel, lieutenant-colonel, major, captain, captain-lieutenant, and captain, and two first-lieutenants. See **ORDNANCE**.

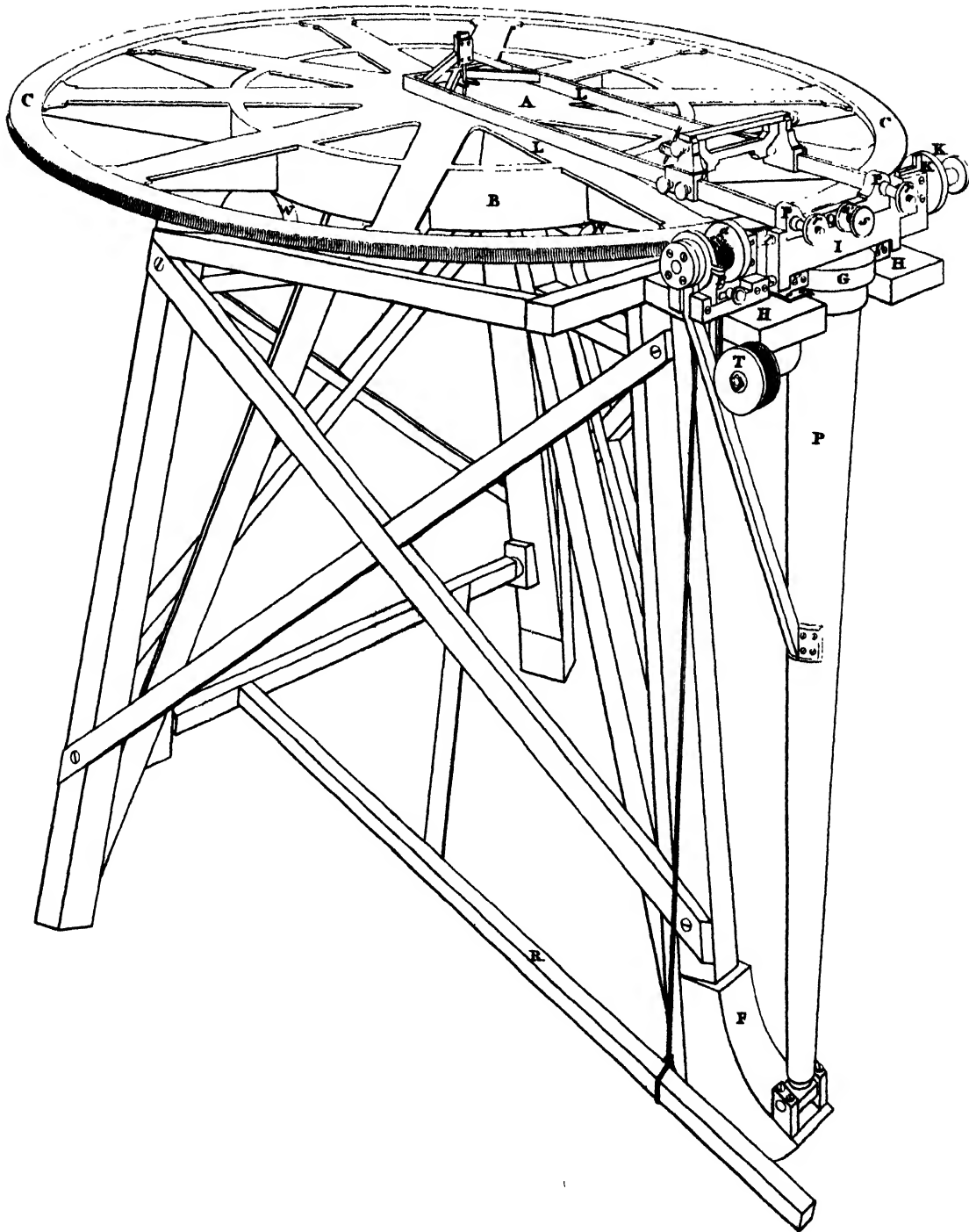
ENGINEERS, Civil, a denomination which comprises an order or profession of persons highly respectable for their talents and scientific attainments, and eminently useful under this appellation, as the canals, docks, harbours, light houses, &c. amply and honourably testify. This order of artists is said to have commenced in this country about the year 1760, at which period the advancement of the arts and sciences was singularly rapid. In 1771, Mr. Smeaton, so well known in this department of science, projected and established an association, or society of engineers. During an interval of 20 years, the number of members of this society increased to 65, of whom 15 were real engineers, and the residue being composed either of amateurs, or of ingenious workmen and artificers. In May 1792 this society

was dissolved in consequence of an unpleasant circumstance, which had interrupted its harmony; but a renewal of it, under a better form, was soon intended, though not accomplished during the life-time of Mr. Smeaton. His death happened in October 1792, and the first meeting of the new institution, entitled "The Society of Civil Engineers," was held on April 15, 1793, by Mr. Jessop, Mr. Mylne, Mr. Rennie, and Mr. Whitworth. According to the new constitution of the society, it is divided into three classes. The first class, as ordinary members, consists of real engineers. The second class, as honorary members, is composed of men of science, and gentlemen of rank and fortune, who have attended to the subject of civil engineering. The third class, as honorary members also, consists of artists, whose professions and employments are connected with what is called civil engineering. The meetings are held at the Crown and Anchor, in the Strand, every other Friday, during the session of parliament. See Reports of the late Mr. John Smeaton, F.R.S. &c. vol. i. 4to. 1797.

ENGINES.

PLATE VII.

A perspective View of M^r RAMSDEN'S dividing Engine.



ENGINES.

PLATE VIII.

M^r RAMSDEN'S DIVIDING ENGINE.

Fig. 2.
PLAN
of the Great Wheel.

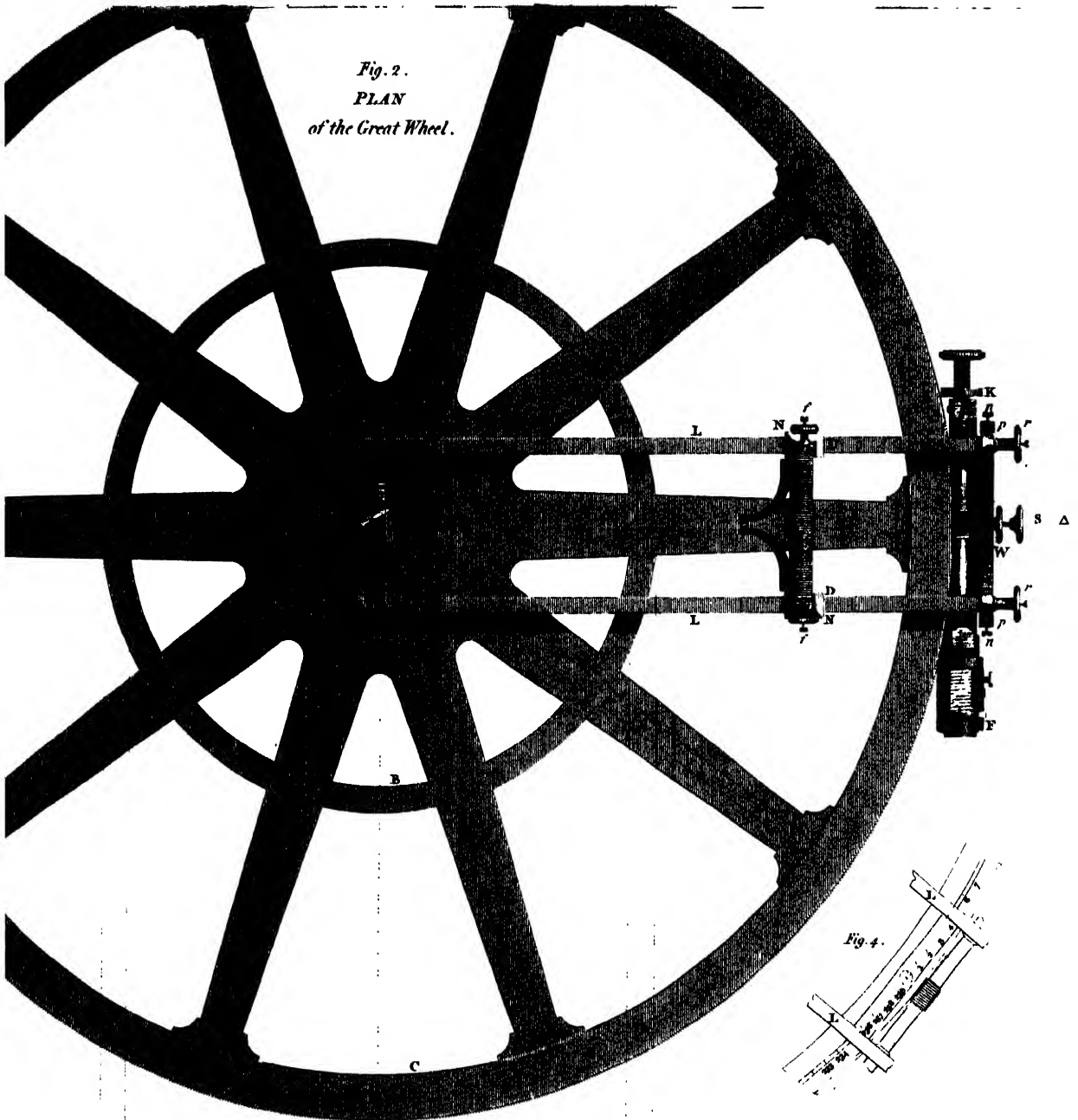


Fig. 4.

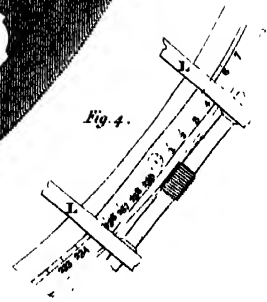
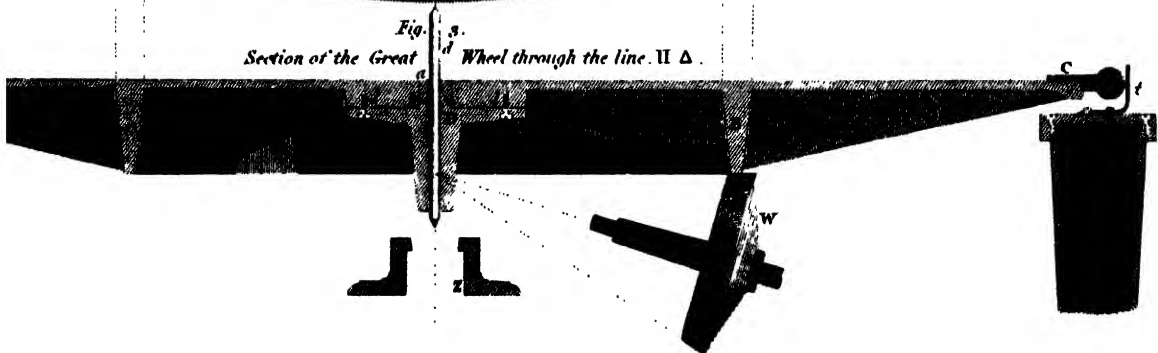


Fig. 3.
Section of the Great
Wheel through the line. II Δ.



ENGINES.

PLATE IX.

M^r RAMSDENS DIVIDING ENGINE.

Section of the screw.

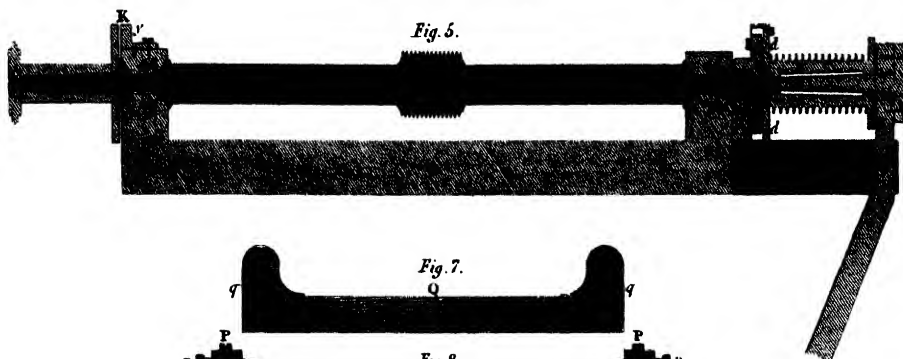


Fig. 6.



Fig. 7.



Fig. 8.

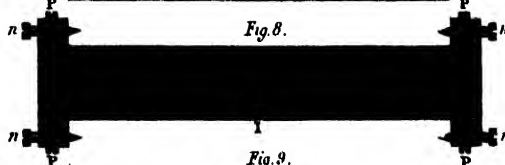


Fig. 9.

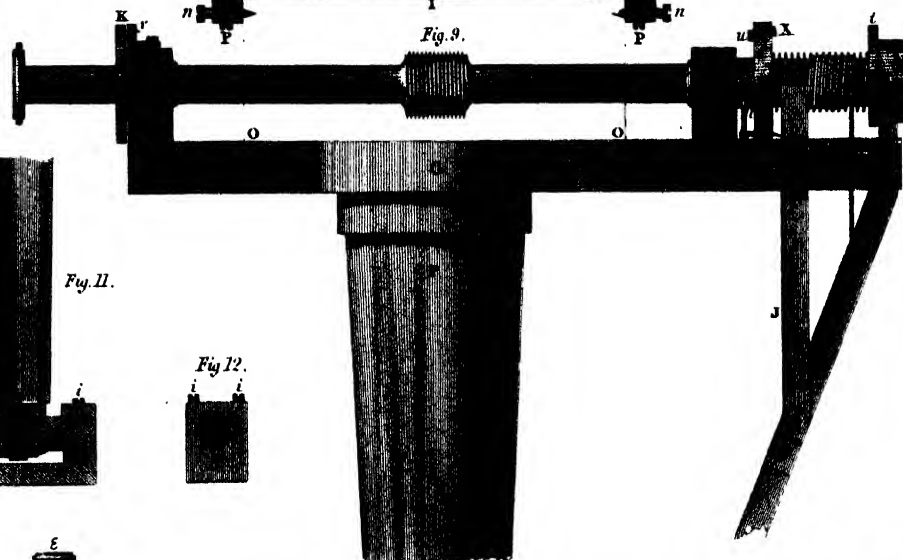


Fig. 10.

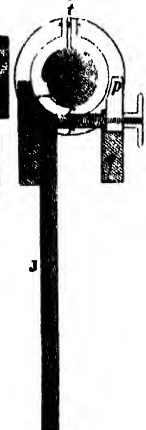


Fig. 11.

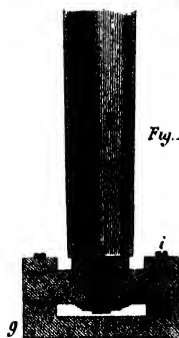


Fig. 12.



Fig. 13.

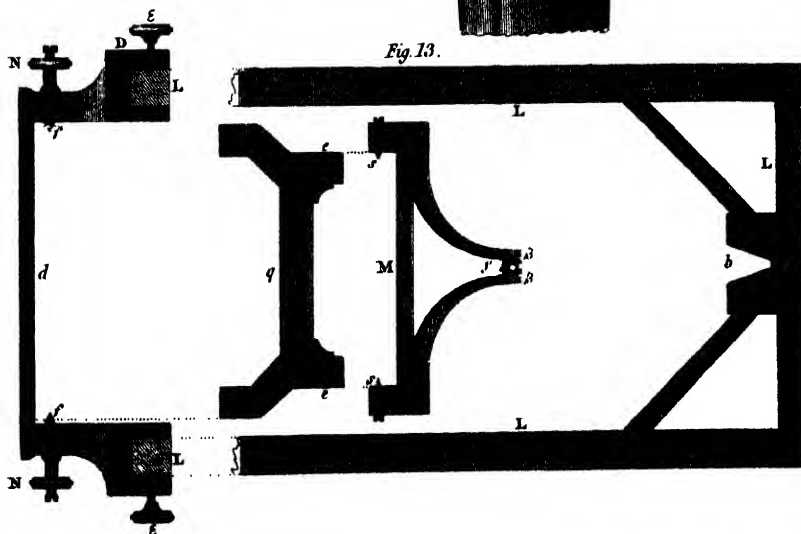
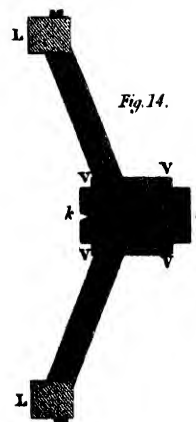
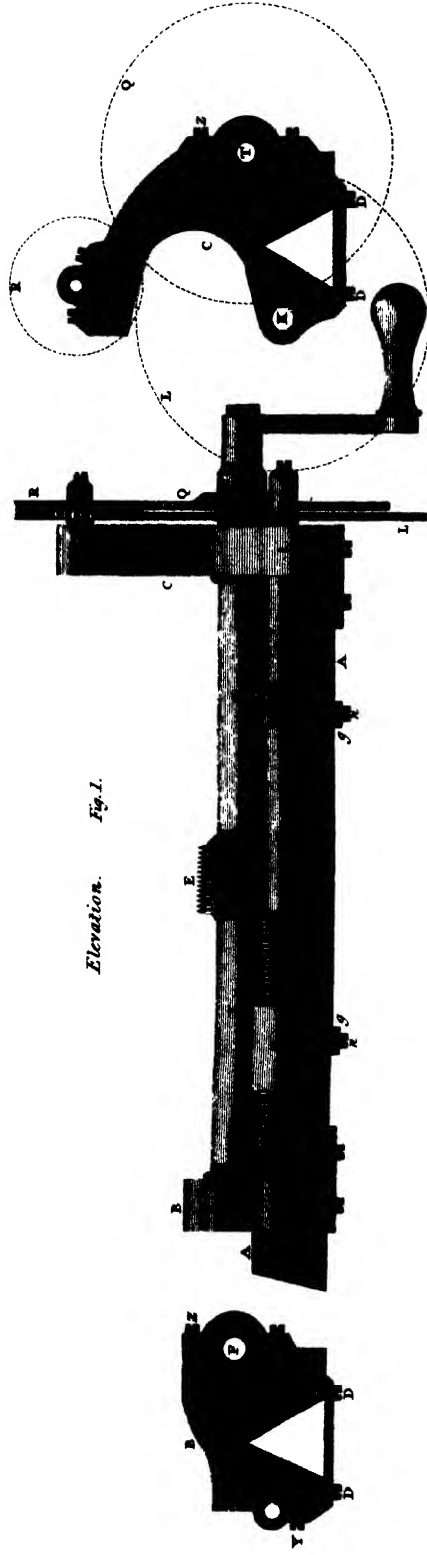


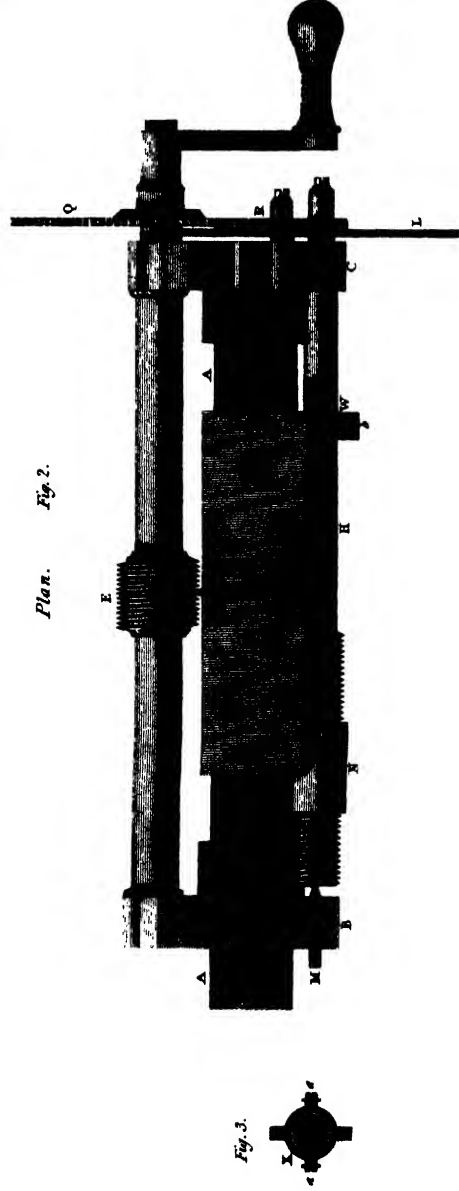
Fig. 14.



Engine for cutting the Screw of Ramsden's Circular Dividing Engine.



Elevation. Fig. 1.



Plan. Fig. 2.



Fig. 3.

ENGINES.

PLATE

ENGINE for cutting the screw of RAMSDEN'S Straight Line dividing Engine

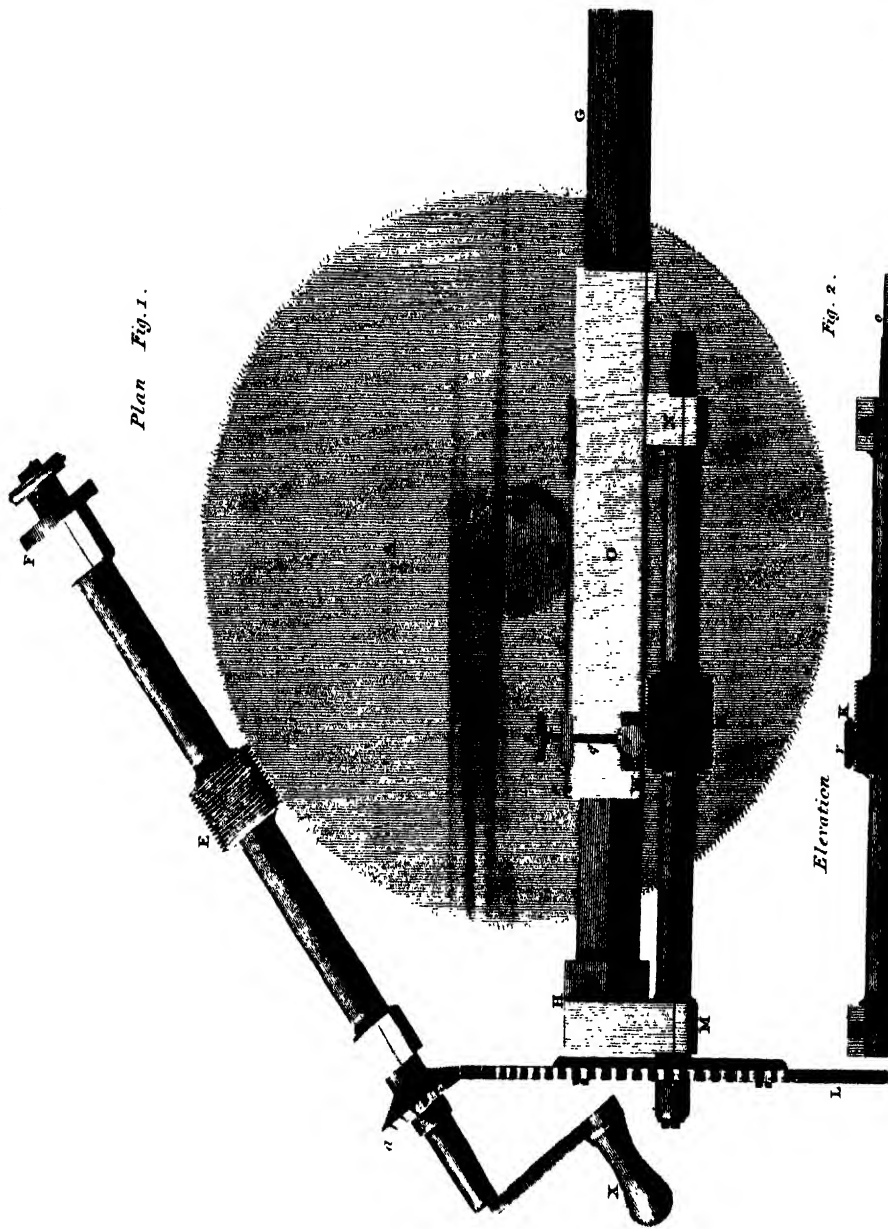


Fig. 1.

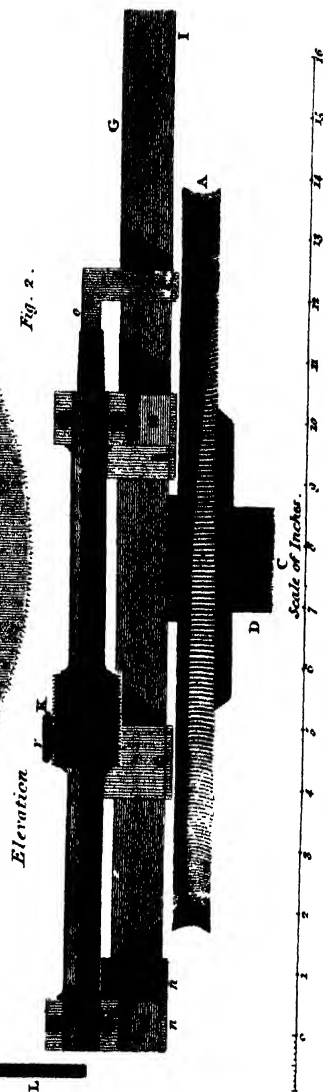


Fig. 2.

Elevation

Scale of Inches.

Drawn by J.

Published as the Act directs, 1841, by Longman, Hurst, Rees, Orme & Brown, Paternoster Row.

Fig. 1

RAMSDEN'S ENGINE for dividing Straight Lines.

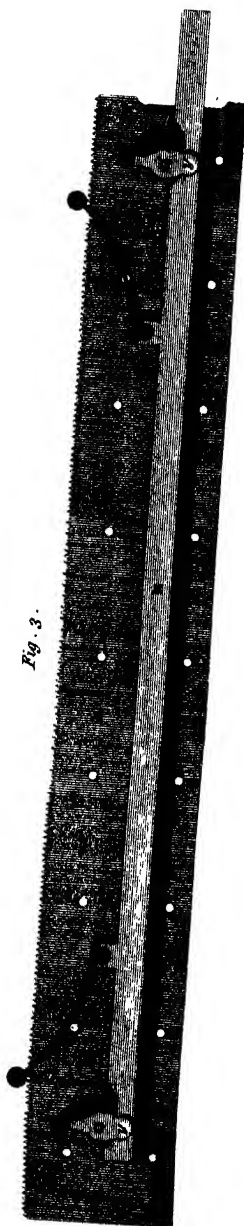


Fig. 3.

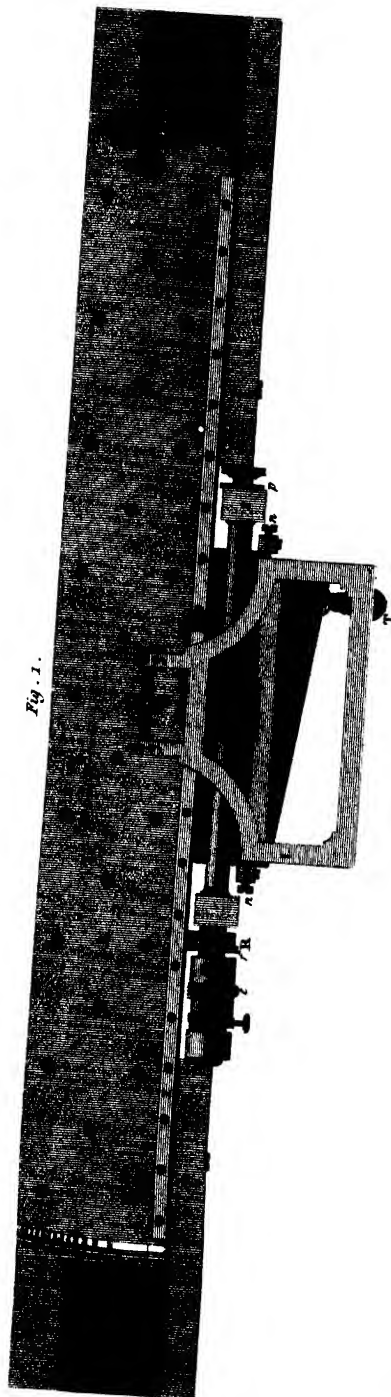


Fig. 1.

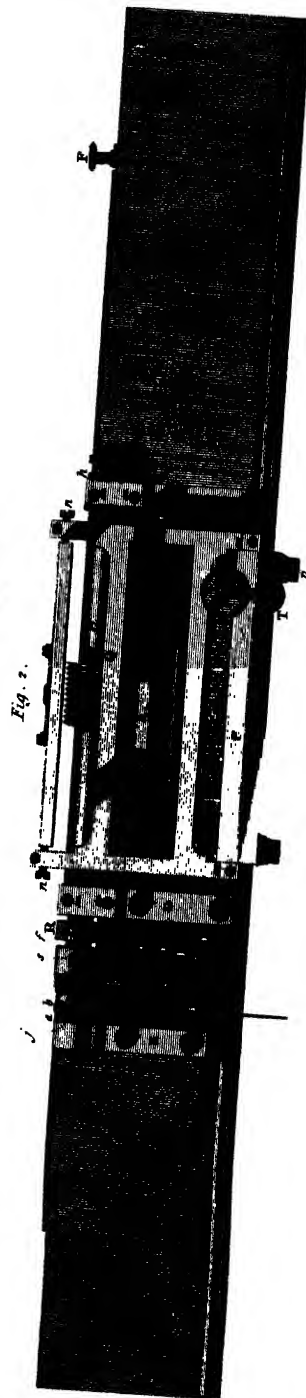


Fig. 2.

J. Perry, New York.

Published as the Act directs, 1820 by Longman, Hurst, Rees, Orme & Brown, Paternoster Row.

Engraved by Wilson Lowry.

Ether

ETHER, in *Chemistry*, is a light, odorant, inflammable liquid, produced by the action of certain of the acids upon alcohol. The acids that have actually been employed for this purpose are the sulphuric, the nitric, the muriatic, the acetic, and the fluoric ; whence originate as many species, or perhaps varieties of ether, all of which we shall describe in due order.

§ 1. *Sulphuric ether*.—The method of preparing this substance is first mentioned in the Dispensatory of Valerius Cordus, published about the year 1540 ; it was also known to Basil Valentine, Paracelsus, and Boyle : it had, however, attracted the notice of chemists only in a very imperfect degree, before it was described by Froben, a German, in the

Philosophical Transactions for 1730. Since that period the preparation and properties of sulphuric ether have been carefully investigated by many able chemists, especially Scheele, Dollfus, Macquer, Pelletier, Vauquelin and Fourcroy.

The mode of obtaining ether in the small way is as follows. Take a tubulated glass retort, of the capacity of about six quarts, lengthen its beak by an adapter, and pass the other end of the adapter into a two-neck quilled balloon receiver; fix another adapter into the opposite neck of the balloon, and join to this a common quilled balloon receiver, placed in such a position that the quill, instead of pointing directly downwards, as in the first receiver, shall slant gently upwards; then lute all the junctures with linseed meal or common paste, except that of the retort to the first adapter; fix also a 24 ounce vial to the quill of the first receiver, and loosely close the quill of the second with a cork or plug of moist paper. The lute being moderately dry and hard, withdraw the retort, and pour in through the tubulure 40 ounces by weight of rectified alcohol, and 32 ounces of the strongest sulphuric acid. Replace the retort with its contents, being careful to shake it as little as possible, and let it remain for 12 hours or more, during which the acid and alcohol will gradually act on each other, producing a considerable degree of heat. Afterwards withdraw the retort, and mix together its contents as accurately as possible, by communicating to them a gentle circular motion; this being finished, replace the retort, and carefully close by lute its junction with the adapter, and leave the whole in this state till the contents of the retort have acquired a reddish-brown colour, which will take place in a day or two. Now proceed to distillation, by placing a pot of lighted charcoal beneath the retort, observing to heat it very gradually. The first impression of the fire drives off a little highly dephlegmated alcohol, but as soon as the mixture begins to boil, the ether itself passes over and condenses on the sides of the receiver in large streaks. It is now essentially requisite to keep the receiver as cool as possible, by the application of ice or of wet cloths wrung out in cold water and frequently renewed; and if this is properly attended to, by far the greater part of the ether will be condensed in the first receiver, whence it will flow into the vial beneath; a little, however, will pass through the second adapter into the second receiver, where it must be condensed by the same means as have already been recommended. The contents of the retort are to be kept moderately boiling, till sulphurous acid gas begins to pass through the quill of the second receiver, which may be known at once by its strong suffocating odour. As soon as this is perceived, the fire is to be withdrawn, and the vial is to be detached from the receiver, and its contents poured into a ground-stoppered bottle; being then replaced as before, the process of distillation is to be re-commenced till about six or seven ounces of a coloured liquid are produced, after which the operation is to be stopped. The original mixture of sulphuric acid and alcohol is thus divided into three separate products; namely, the residue in the retort, and the products of the second and first distillations. In the retort is a black thickish matter, smelling strongly of sulphurous and acetic acids, and intensely sour to the taste. If diluted with an equal bulk of warm water and filtered through pounded glass or clean white sand, it will be separated from the carbonaceous matter with which it was loaded, and by subsequent boiling the sulphurous and acetic acids will be driven off, leaving behind sulphuric acid in a considerable degree of concentration, and applicable to a variety of useful purposes. The product of the second distillation consists of two distinct liquids, the heaviest of which is acidulous

water, and the lighter an impure ether, called *oil of wine*, which may be separated from the water by inverting the vial that contains them in warm water; a little of the ether is in consequence converted into elastic vapour, which forces out of the vial the lower and heavier fluid. The product of the first distillation is impure ether, in quantity about $17\frac{1}{2}$ ounces. Thus from 32 ounces of sulphuric acid and 40 ounces of alcohol there are procured about $17\frac{1}{2}$ ounces of impure ether, and three ounces of oil of wine; and the sulphuric acid that may be recovered, taking into consideration its quantity and density, amounts to about 46 per cent. of that originally employed.

Ether, when fresh distilled, is contaminated by sulphurous and acetic acids and a little coloured oil, in consequence of which it is necessary to purify it by rectification. This is generally done by adding to the ether successive portions of caustic potash or soda dissolved in water, and shaking together the two fluids in a well closed bottle, after each addition of alkali, till the sulphurous odour is totally destroyed; the contents of the bottle are then to be poured into a retort, and by the application of a gentle heat, never amounting to ebullition, the ether will pass into the receiver in a state of great purity, leaving behind a watery saline liquor covered by a thin film of brownish-yellow oil. Scheele recommends that the alkali employed in rectification should be dissolved in alcohol instead of water; the advantage of which is that no spontaneous separation of the liquors takes place, and therefore the sulphurous and acetic acids are neutralized and separated with greater certainty. Distillation at a gentle heat will readily separate the ether from the other ingredients. A still cheaper and very effectual method of rectifying ether is the following, first employed by Mr. Woulfe. "Fill three-fourths of a bottle with the impure ether, add a little water and a portion of slacked lime; agitate the bottle with violence, and keep it for some time in cold water, before taking out the cork; if the smell of the sulphurous acid be not removed, add a little more lime and agitate a second time. Decant off the ether into a receiver, and distil it off." Another very cheap and ingenious process was invented by Pelletier. It consists in adding to the impure ether a little finely pulverized black oxyd of manganese. The mixture being corked up in a bottle, is to be well shaken four or five times a day for the space of a week, at the end of which time the sulphurous acid will have been converted into sulphuric, and will have combined with the manganese, from which the ether may be poured off without the necessity of distillation.

By any of the above methods ether is rectified sufficiently for any purposes to which it is usually applied; but if the greatest possible degree of purity is required, there should be added to the rectified ether successive portions of dry pulverized muriatic lime, till it ceases to be dissolved; from this mixture, by distillation with a very gentle heat, and keeping at the same time the receiver quite cold by the application of ice, an ether may be procured, probably entirely free from alcohol and water, and of the specific gravity of 0.65.

Rectified ether exhibits the following properties. It is a transparent colourless liquor, of a peculiar and to most persons an agreeably fragrant odour, and a hot penetrating, and somewhat suffocating taste. Its usual specific gravity, according to Lavoisier, is = 0.758. It is volatilizable at a lower temperature, and more rapidly than any other liquid, a considerable proportion being lost, especially in hot weather, by merely pouring it from one vial into another; hence the vessels in which it is kept ought to be very exactly closed, and for further security are often kept inverted in cold

water. It boils at 98° Fahr. under the usual atmospherical pressure, and at 20° in vacuo.

Owing to the extraordinary rapidity with which ether evaporates, it possesses a very great power of refrigeration. This is made obvious to the feeling by pouring a little into the palm of the hand; it is almost instantly volatilized, and the hand becomes painfully cold. So also if some fine tow is wrapped about the bulb of a small thermometer, and the blast from a pair of double bellows is let upon it, after it has been well soaked in ether, the mercury in the thermometer will, in the space of a minute or less, be lowered to 0° Fahr. Ether, notwithstanding its ready volatility, is capable of being congealed at a low temperature. If a small matras filled with this fluid is cooled (down to -25° Fahr. by a mixture of snow and muriat of lime, the liquor becomes gradually filled with brilliant transparent crystalline laminæ, resembling benzoic acid or oxymuriat of potash; and presently, especially at a somewhat lower temperature, the whole is congealed into a white almost inodorous mass. Ether is remarkably inflammable, taking fire instantly on the near approach of an ignited body; it burns with a large white flame and a little smoke, and is resolved into water, carbonic acid, and a minute quantity of charcoal. When passed through a red-hot earthenware tube, it is entirely decomposed, and a large production of carburetted hydrogen takes place. Ether remarkably increases the bulk of any of the permanent gasses to which it was added, as was first observed by Dr. Priestley. A small quantity of this fluid being mixed with oxygen confined over mercury, exactly doubled its bulk, nor could any additional quantity occasion a further dilatation. Nearly the same effect took place with atmospheric air, azot, hydrogen, nitrous gas, and carbonic acid; but by a slight agitation in water the ether was absorbed, and the gas resumed its former dimensions without any alteration of its original properties. If oxygen gas thus diluted by ether is set fire to, it burns rapidly, but does not explode; but if one part of this mixture is added to three parts of oxygen, the application of an ignited body, or of the electric spark, causes a violent explosion, the products of which are water and $2\frac{1}{2}$ parts of carbonic acid. Hence it appears that one part of ether requires 6.8 of oxygen for its saturation, and that the proportion of carbon to hydrogen in sulphuric ether is nearly as 5 to 1.

Water and ether appear to combine with each other in two different proportions. If equal parts of these fluids are shaken together in a graduated tube, the ether will be found to have diminished in bulk about $\frac{1}{3}$, and the water to have enlarged in nearly the same proportion; the lower fluid consists of water saturated with ether, and the upper fluid is ether combined with a little water. The ether in this state is said to be *washed*, and acquires in consequence some properties which pure ether does not possess; in particular, it is now capable of dissolving caoutchouc with great ease, whereas this substance is acted on by pure ether only in a very imperfect manner. Phosphorus is soluble in ether, but the solution is not luminous. When ether is boiled with phosphorus, it often deposits crystals by cooling; agitation with water produces no change in this liquid, but the addition of a little alcohol causes an immediate turbidity, whence the sophistication of ether by alcohol may be detected by the addition of a few drops of phosphorized ether. The fixed alkalies seem incapable of uniting with ether, but ammoniacal gas is absorbed by it very copiously. The same may be observed of nitrous gas; but neither of these combinations has hitherto been submitted to an accurate examination. Sulphuric acid acts on ether with considerable energy, especially if assisted by a gentle heat; it is converted

into a brownish oily fluid, much heavier than ether, called oil of wine, and at a higher temperature is changed into olefant gas. With regard to the action of oxymuriatic acid on ether, a curious experiment is related by Mr. Cruickshank. "If we fill a bottle of the capacity of three or four pints with the pure oxymuriatic acid gas, taking care to expel the water as completely as possible, and then throw into it about a drachm or half a drachm of good ether, covering its mouth immediately with a piece of light wood or paper, in a few seconds white vapour will be perceived, moving circularly in the bottle; this will soon be followed by an explosion, accompanied by flame, at the same time a very considerable quantity of carbon will be deposited, and the bottle will be found to contain carbonic acid gas." Nitric acid excites a considerable effervescence in ether, and seems to convert it into oil of wine. The essential oils are soluble in ether, and it combines with alcohol in almost all proportions.

Concerning the theory of etherification, much has been written, and many experiments have been made by able chemists, without, however, obtaining the satisfaction that could be wished. According to Macquer, ether is a substance intermediate between alcohol and oil, and alcohol approaches to the state of oil precisely in proportion as it parts with its water of composition. But though it is true that the production of water accompanies the conversion of alcohol into ether, and of ether into oil of wine, yet this is by no means the only phenomenon, so that the theory of Macquer is, at best, imperfect, since the deposition of charcoal, and the generation of acetous acid, are not at all accounted for. According to Pelletier, Chaptal, and others, the whole process of etherification consists in a transfer of oxygen from the sulphuric acid to the alcohol: the disengagement of sulphurous acid accompanies the production of ether, and therefore shews that the sulphuric acid is deoxygenated: the oxygen, thus separated, does not come over in the state of gas, and therefore must be combined with the alcohol forming ether. But in reply, it may be observed, that this mode of explanation accounts for only a few of the phenomena, and that the preparation of ether, if carefully managed, may be carried on without the disengagement of any sulphurous acid. The most elaborate enquiry into this intricate subject was undertaken by Vauquelin and Fourcroy, which we shall now proceed to detail, though it is by no means so complete and satisfactory as to preclude the necessity of further researches. The facts and observations by which this theory is supported are the following.

If one part of alcohol and two of sulphuric acid are mixed together, the temperature rises to about 200° Fahr.; the mass immediately acquires a deep brownish-red colour, which deepens into black in a few days after, and at the same time exhales a vapour manifestly ethereous.

Equal parts of concentrated sulphuric acid and rectified alcohol acquire on mixture a temperature of 190° Fahr.; bubbles of gas are extricated, the liquor becomes turbid and opalescent, and at the end of a few days acquires a deep red colour. The whole being then transferred to a distillatory pneumatic apparatus, and being heated to 107° Fahr., ebullition takes place, and ether passes over into the recipient; if the operation is carefully conducted no elastic fluid is disengaged, and the vapour, when condensed, is found to be only water and ether. When the liquor thus obtained amounts to about half of the alcohol employed, sulphurous acid begins to be manifest, and, in a short time, the production of ether ceases, and is succeeded by oil of wine, accompanied by acetous acid. The contents of the retort being kept boiling, and becoming more and more concentrated as

the distillation proceeds, are constantly acquiring a higher temperature; when this amounts to about 234° Fahr., olefiant gas begins to come over, and continues till the oil of wine ceases to flow. At this period carbonic acid gas first makes its appearance, and water and sulphurous acid still continue to be produced, the residue in the retort being in the mean time reduced to little else than sulphuric acid thickened by charcoal.

From these facts the able chemists who observed them have concluded,

1. That the spontaneous action of alcohol and sulphuric acid, when this latter is considerably in excess, is sufficient for the formation of ether without the assistance of any extraneous heat, and that by duly proportioning the two substances, the alcohol might be wholly decomposed and made to yield all the ether of which it is capable when treated in the usual manner.

2. That the formation of ether is not owing to the affinity of the oxygen of the sulphuric acid, for the hydrogen and carbon of the alcohol, because in the preparation of ether no sulphurous acid gas is evolved till the production of ether has almost ceased. It must therefore be the entire attraction of the acid for one or more of the elements of the alcohol that determines its decomposition: now since water is formed during the whole process, and, since the attraction of sulphuric acid for this substance is very powerful, it appears likely that this is the cause that destroys the equilibrium of the affinities by which the elementary particles of alcohol are retained in combination, and induces the oxygen and hydrogen to unite and form water. Hence it might at first sight be supposed that ether differs from alcohol in containing a smaller proportion of oxygen and hydrogen. This however will not be found to be the case, when we advert to the deposition of charcoal, which, equally with the production of water, accompanies the formation of ether: now the amount of charcoal deposited is greater in proportion to that which is left, than the hydrogen of the water compared to what remains in the ether; therefore this latter fluid, though composed of the same elements as alcohol, differs from it in containing a smaller proportion of carbon compared with the hydrogen. During the progress of distillation the heat to which the materials in the retort are exposed is constantly increasing, and (the affinity of the acid and alcohol also augmenting) the acid itself is at length decomposed, sulphurous acid is generated, and the excess of oxygen deprives the alcohol of part of its hydrogen whence results the oil of wine, differing from ether in containing a larger proportion of carbon; and in confirmation of this, it may be observed, that the charcoal deposited during the production of oil of wine is not so abundant as during the generation of ether.

Hence as (according to the authors of the above hypothesis) no decomposition of the sulphuric acid takes place during the formation of ether, the agency of the acid is partly that of detaining the alcohol in a temperature more than sufficient for the volatilization of this fluid when uncombined, and partly that of assisting the caloric to decompose the alcohol in consequence of its own powerful affinity for water.

A circumstance, however, first remarked by Scheele, but which has hitherto failed to obtain the notice to which it is so well entitled, sufficiently proves that in the formation of ether the acid employed acts a much more important part than is assigned to it in the theory of Vauquelin and Fourcroy. The admirable chemist above-mentioned states that if sulphuric ether be duly rectified by agitation with caustic alkali and subsequent distillation, it occasions no precipitate with barytic salts; but if to the ether thus purified there be

added nitric acid, a copious precipitate is then produced by any of the soluble salts of barytes, indicating the presence of sulphuric acid. This fact strikingly points out that a portion of the base of the acid in a more or less deoxygenated state actually combines with the alcohol to compose ether. A like fact respecting muriatic ether is also mentioned by Scheele, namely, that though this ether, when rectified, occasions no decomposition of nitrated silver, yet the watery residue, after combustion of the ether, occasions a copious precipitate of muriated silver when mixed with the nitrate of this metal.

§ 2. *Nitrous ether*.—Although nitrous ether appears to have been known to Basil Valentine and Kunkel, yet the mode of its preparation being kept a secret, it soon ceased to be attended to by chemists, till in the year 1740 it was re-discovered by Duhamel, and afterwards was more particularly described by Navier, Sebastiani and others. It was prepared by Navier in the following manner. Put 12 ounces of rectified alcohol into a strong bottle, and add to it gradually and at intervals 8 ounces of strong nitric acid; after each portion of acid the liquors are to be well mixed by agitation, and the bottle is to be kept close corked and immersed up to its neck in ice and water; when the whole of the acid has been added, the bottle is to be well corked and further secured by a leathern cap. A stratum of ether rises by degrees to the surface of the liquor, and after five or six days the cork is to be pierced by a needle in order to let out the nitrous gas formed during the process: this gas having escaped, the cork is to be drawn, and the whole contents of the bottle being poured into a separatory funnel, the ether is thus procured unmixed with the heavier fluid on which it floats. This is, however, a very rude way of proceeding, and is attended with the utmost risk to the apparatus, the ether obtained also is in small quantity, and very impure. In order to prevent the violent and rapid action of the concentrated acid on the alcohol, which is the chief difficulty in the preparation of nitrous ether, Dr. Black proposed to interpose a thin stratum of pure water, and Fischer on the same principle made use of a little weak spirit of nitre for the same purpose. M. Dölsfus, from a careful repetition of the latter process, obtained the following result. Upon two ounces of very strong nitric acid he poured gently six drachms of the same very much diluted, and upon this three ounces of rectified alcohol. The bottle was loosely corked and suffered to stand undisturbed for three days; at this time the lower liquor appeared perfectly homogeneous with a stratum of ether floating above it. The whole being put into a retort and subjected to a gentle heat, there were obtained two ounces and a drachm of very pure ether unmixed with any acid, and the residue in the retort consisted of weak acetous acid mixed with oxalic acid, nearly the whole of the nitrous acid having been decomposed.

The last mode by which nitrous ether may be prepared, that we shall mention, and which on the whole appears to be the best, consists in mixing together alcohol and sulphuric acid, and pouring the liquor upon pulverized nitre; the sulphuric acid disengages the nitre, which immediately re-acts on the alcohol, and ether is the result. The able chemist whom we have already mentioned has shewn the excellence of this method by the following experiment. Having put into a retort four ounces of perfectly dry and pulverized nitre, he added to it a mixture consisting of two ounces of concentrated sulphuric acid, and four ounces of alcohol. The whole being submitted to distillation, there came over first six drachms of dulcified spirit of nitre, and then three ounces of a liquor from which by subsequent rectification were procured two ounces of pure ether.

Nitrous ether, when recently made, contains in loose combination a considerable quantity of nitrous gas, which in some degree modifies its properties, and renders it peculiarly liable to burst the bottles in which it is kept, especially in warm weather. This loss and trouble, however, may be avoided by rectifying the ether, which is best done in the following way. Pour into a strong vial so as to fill it two thirds, one part of ether and four parts of pump-water, and agitate it cautiously at first, frequently removing the thumb from the mouth of the vial in order to afford a free passage to the disengaged nitrous gas; when no more of this gas is given out add a quantity of dry pearlash equal in weight to the ether, and shake the whole well together; then put the mixture into a tubulated retort and proceed to distillation, taking care that the temperature does not exceed 120° Fahr.; the ether will pass into the receiver quite pure, and may be kept for any length of time in strong well closed bottles, with no more risk of accidents than sulphuric ether is subject to.

Nitrous ether resembles sulphuric ether in most of its properties; it has, however, a dilute yellow colour, and a somewhat different odour and flavour; this appears to be owing to the presence of a little resinous matter, from which it can never be entirely freed; by repeated distillations from fresh parcels of dry white sugar, as Deyeux has observed, this impurity may, in great part, be separated, and in proportion as this takes place the ether becomes more and more analogous to that prepared by sulphuric acid.

Nitrous ether appears capable of uniting with nitrous gas in two proportions; when the ether is in excess it forms nitrous ether in the state in which it appears previous to rectification; when the nitrous gas exceeds the ether it forms a permanently elastic fluid that has obtained the name of *etherized nitrous gas*. The preparation of this differs only in the rapidity with which the nitrous acid and alcohol are made to act on each other: when the combination takes place very slowly much ether and little etherized gas are the result, but when the contrary is the case, these two products are formed in an inverse proportion. If equal parts of alcohol and strong nitrous acid are mixed together at the common atmospheric temperature, or at a higher heat in proportion as the acid is diluted, a very rapid and copious effervescence takes place, a little ether is condensed in the receiver, and a large quantity of gas passes through the conducting tube, the first portions of which are etherized nitrous gas, and the latter common nitrous gas. What remains in the retort is acetic acid with a little oxalic acid. The properties of etherized nitrous gas (according to Van Diemen and his associates, to whom we are indebted for its discovery) are the following. It has a disagreeable ethereal odour, exactly resembling that of olefiant gas when treated with oxymuriatic acid. By the application of flame it takes fire and burns with a yellowish lambent flame like alcohol; after the combustion has ceased, the vessel in which it was carried on contains a vapour of singular pungency. Water absorbs this gas, but requires a considerable time to effect this, except agitation is had recourse to, resembling, in this respect, carbonic acid. Alcohol produces the same effect as water, and takes up the gas not only more rapidly, but also in larger proportion. A solution of caustic potash also dissolves it, but with considerable difficulty, and on the addition of sulphuric or muriatic acids the etherized gas is again set at liberty unaltered in any of its properties. Ammonia, whether liquid or in the gaseous state, is incapable of contracting any union with it; the same is the case with oxygen gas at the common temperature, but a mixture of the two airs, when inflamed, produces a most violent explosion; sulphuric acid immediately decomposes this gas, by absorbing the

ether, the nitrous gas retaining its elastic state. Sulphurous acid produces the same effect, only it requires some days for this purpose. If sulphuric acid, previously diluted with an equal weight of water, is placed in contact with this gas over mercury, its action is greatly retarded, the diminution of volume in the inclosed air takes place much more slowly, and even after some days a portion of ether is retained by the nitrous gas, which in consequence acquires the property of enlarging the flame of a taper that is immersed in it, in the same manner as nitrous oxyd does. Nitrous acid, according to the degree of its concentration, absorbs either wholly or in part, the ethereous portions of the gas, and the same may be observed of muriatic acid.

Etherized nitrous gas, when passed through a red-hot tube, deposits a little oil, and by subsequent washing in lime-water is freed from some carbonic acid; the residue is nitrous gas, mixed or combined with common carburetted hydrogen, and is not acted on by the sulphuric, nitric, or muriatic acids, by caustic potash or alcohol. The addition of oxygen gas produces red vapours, the nitrous gas is converted into acid, and the gaseous residue is carburetted hydrogen.

§ 3 *Muriatic ether*.—After chemists had shewn the production of ether by means of the sulphuric and nitric acids, it was natural to attempt its preparation by the muriatic acid. But this latter, in its usual state of dilution with water, has no action on alcohol, and therefore the various modes that were first practised to obtain muriatic ether entirely failed. A few chemists were said to have succeeded by employing simple muriatic acid, but in a more concentrated and dry state than the common liquid acid; the process, however, was both difficult and doubtful, and muriatic ether can hardly be said to have been known till Rouelle discovered that it might be prepared by distilling together alcohol and the smoking liquor of Libavius, which is a concentrated muriat of tin in its highest state of oxydation. The marquis de Courtanvaux, having repeated the process of Rouelle with great care, proposes the following as the best method of making the substance in question. Mix together in a retort three parts of the fuming muriat of tin and one of alcohol; a considerable degree of heat is immediately excited, and a white suffocating vapour arises, which, however, soon disappears on agitating the mixture. As soon as an ethereous odour is perceived, let two balloon receivers be luted on, and kept as cool as possible; then by the application of a gentle heat to the retort there comes over first a little dephlegmated alcohol, which is succeeded by the ether: by an increase of temperature a few drops of coloured oil are produced, and there arises, partly in the form of a soft butter and partly in that of a dense brown liquid, a quantity of smoking muriat of tin, part of the metallic oxyd remaining in the retort as a grey powder. When the ether thus procured is mixed with pearlash, a copious effervescence and precipitation take place, owing to the decomposition of some muriat of tin contained in the ether; after which, by distillation at a gentle heat, the ether arises in a state of great purity, amounting to half the impure product of the first distillation.

Several other of the metallic muriats have been found to be equally efficacious with the liquor of Libavius; the corrosive muriats of antimony and of arsenic, the muriats of bismuth and zinc, and the red muriat of iron, have in particular been used with success in the preparation of muriatic ether. Scheele.

Scheele, the discoverer of oxymuriatic acid, was induced to try the effect of this in the preparation of muriatic ether. For this purpose he put three ounces of alcohol into a

receiver, with which was connected a retort holding two ounces of common salt, upon which was poured an equal weight of sulphuric acid; the muriatic acid thus disengaged passed into the receiver, where it combined with the alcohol; and this, when saturated with acid, was transferred to another retort, containing three ounces of black oxyd of manganese in fine powder; the mixture instantly assumed a green colour, and presently after became so hot as to boil. When the ebullition had ceased, there was found in the receiver a liquor, from which, on mixture with water, a quantity of ether immediately separated. The same method is recommended by Van Mons, except that he employs only one fourth of the manganese used by Scheele, and performs the second distillation in a Woulfe's apparatus, the bottles of which contain a solution of caustic potash, by which the acid is prevented from re-acting on the ether.

Another mode of applying oxymuriatic acid to the preparation of ether, first practised by Scheele, is mentioned by Pelletier, and deserves to be repeated, as being perhaps the most expeditious and economical of any. He introduced into a large tubulated retort a mixture of eight ounces of manganese, and 16 ounces of decrepitated common salt, upon which he poured a mixture of 12 ounces of sulphuric acid, and eight ounces of alcohol. From this mass ten ounces were drawn off by distillation at a gentle heat, which, by subsequent rectification, yielded four ounces of ether.

It deserves to be remarked that the ether prepared by oxymuriatic acid generally deposits, during its rectification with potash, a considerable quantity of a clear aromatic and bitter oil, which sinks in drops to the bottom of the vessel; the ether also, according to Dollfus, at least before rectification, is completely miscible with water when shaken with it for some time. The preparation of ether, by means of simple muriatic acid, is not easy, and was readily supposed to be impossible by some of the leaders of the modern school of French chemists, because it contradicted one of their early theories on the process of etherification; yet Beaumé, a chemist of great experience and unquestioned veracity, had affirmed, that he had obtained a small quantity of ether, by mixing together alcohol and muriatic acid, both of them in the state of vapour. The practicability of this method appears also to be established beyond doubt by the following formula of M. Basse. Keep a quantity of common salt in fusion for about an hour, in order to drive off all the water of crystallization, then pulverize it, and put 40 parts into a tubulated retort, connected with a Woulfe's apparatus, in the first bottle of which are to be poured 20 parts of most highly rectified alcohol; then add to the salt in the retort 20 parts of the strongest sulphuric acid, and proceed to distillation by a gentle heat, keeping the bottle holding the alcohol as cool as possible. When the alcohol is saturated with acid, transfer it to a retort, and distil over about one half of it; agitate this portion with an alkaline ley, and the ether will presently separate and float on the surface, whence it may be obtained by decantation or distillation. The quantity of ether from the above materials amounts to about five parts.

Muriatic ether has a striking resemblance to that prepared by sulphuric acid; its specific gravity, however, is greater, amounting, according to Hermbstadt, to c.84; its taste also has a peculiar astringency like alum, and when burning it exhales a strong acid odour, somewhat resembling that of sulphurous acid.

§ 4. *Fluoric ether.*—All that we know of this substance is derived from the discoveries of Scheele. He first impreg-

nated rectified alcohol with fluoric acid gas, by distilling pulverized fluor spar with sulphuric acid, and placing alcohol in the receiver; the smking spirit thus obtained was distilled with a gentle heat, but no sign of ether made its appearance. Another portion of the acidulated spirit was then mixed with black oxyd of manganese, and by subsequent distillation an ethereous fluid came over, from which, by subsequent rectification, a little ether was obtained of a very agreeable odour, resembling nitrous ether.

§ 5. *Acetic ether.*—Acetic ether was first discovered by the Count de Lauraguais; the method of its preparation was by distilling together equal parts of alcohol and acetic acid. Scheele, Pomer, Bergman, and other chemists, repeated this process ineffectually, and hence were induced to suspect some error. In consequence of these doubts, Pelletier entered into a careful examination of the subject, and has both shewn the reason of the failure of Scheele, and has given the proper method by which to succeed. He distilled together equal parts of alcohol and acetic acid, and drew off a little more than half; this liquor was acidulous, and had an ethereal odour, but no true ether could be made to separate. He then mixed together 12 ounces of strong radical vinegar, and the same quantity of alcohol, and distilled over one half of it at a boiling temperature; this product he poured back into the retort and recommenced the distillation; the produce of this and of a third distillation were in like manner recobobated, and having distilled the whole again for the fourth time, he finally obtained 12 ounces of an ethereous fluid; with this he mixed a quantity of carbonated potash, sufficient to saturate the acid which it contained, and then submitted it to gentle distillation. The first six ounces that came over were pure acetous ether, the next four ounces also contained ether, but not so pure as the former. It is remarkable that during the cohobations a considerable absorption of air took place.

Scheele obtained acetous ether in a much more compendious manner, by mixing together acetat of potash, or of lead, or of copper, with alcohol, and then adding as much sulphuric acid as was requisite to decompose the acetous salt, and distilling the mixture at a low heat. The produce being shaken with water, the ether rises to the surface and may be poured off. From 16 parts acetat of lead, six parts strong sulphuric acid, and nine parts of water, Bucholz obtained six parts rectified ether.

Acetic ether always retains the odour of the acid by which it is formed; it is not so volatile as the ethers procured by the mineral acids; it burns with a lambent blue flame, like alcohol; it is soluble in a little more than twice its bulk of water, and is decomposable into acetous acid by repeated distillations at a very gentle heat.

Various other acids have been distilled with alcohol for the purpose of procuring ether, but with little or no success. Oxalic acid, with an equal weight of alcohol, yielded Bergman a watery somewhat etherized alcohol. Benzoic acid and alcohol, according to Scheele, afford no ether, but when a little common muriatic acid is added to the mixture, an ethereous liquor comes over, of which part floats on water and part sinks in the same fluid. The ether, or the lighter portion, has the odour of benzoic acid, burns with a clear flame and smoke, and is about equal in volatility to acetic ether. The phosphoric, boracic, tartarous, citric and succinic acids, were found by the same able chemist to be incapable of producing ether, either by their own action on alcohol, or when mixed with oxyd of manganese or muriatic acid.

Expanding Rigger

EXPANDING RIGGER, or *Drum*, in *Mechanics*, is a wheel, or rigger, to receive an endless rope; which can be enlarged or diminished in its diameter, to give a greater or less velocity to the rope.

The common expanding rigger is a cast-iron wheel with twelve arms, in each of which a groove is formed, extending nearly from the centre to the circumference, as *A A*, *fig. 5. Plate XXVI. Mechanics*. Against each arm a piece of wood is placed, which has a rebate fitting into the groove, and a screw-bolt passing through both wood and the arm of the wheel; a nut screwed upon the bolt fastens the bolt and wood at any place in the groove: each piece of wood has a groove in it to receive the rope which passes round the wheel. The diameter of this rigger can be altered by loosening the nuts, then placing the pieces of wood all in one circle of the proposed diameter, and fastening them there by the nuts. To facilitate the placing of the pieces of wood in one circle, each arm is divided into inches, and numbered from the centre.

Mr. Andrew Flint, of London, lately received a premium of fifty guineas from the Society of Arts, for two expanding band wheels, or riggers. *Figs. 5, 6, and 7*, are different views of the first of these; *A A* is a cast metal wheel with twelve arms, each divided by a groove from near the centre to the circumference: these grooves receive rebates on the backs of twelve racks *a a*, *figs. 6 and 7*, which have projecting pieces *b, b*, with grooves to contain the endless rope *d d*. In *fig. 5*, which is a back view of the wheel *cc*, are nuts, which draw up the racks to slide in the grooves without shake, yet freely to and from the centre: the racks are moved all together by means of a circular plate *d d*, which has a spiral rib upon it entering between the teeth of each rack, so that when the plate is turned round, all the racks move to or from the centre at once: the spiral plate *d d* is screwed to an iron cross, which fits upon the axis *ff*, and is turned round by a pinion *g* of six teeth, working into a ring of teeth made in the inside of the spiral plate *d*.

Another method of accomplishing the same object is by means of twelve screws *b* (*figs. 8. and 9*) pointing to the centre of the wheel; they are all moved together by means of equal bevelled wheels fixed on them; by this means the screws are turned about contrary ways alternately:

they must, therefore, be alternately cut right handed and left handed, that they may produce the same effect. The screws are turned, when the diameter of the rigger is to be altered, by a winch put upon any of the three squares *h, h, h*, on the ends of the screws. In this machine the number of screws must be even.

Figs. 10, 11, and 12, are drawings of an expanding rigger contrived by the writer of this article: it consists of two wheels of cast-iron *A, A*, (*figs. 10, 11, and 12*.) which have sixteen sectorial apertures marked *a*, which leave sixteen arms between them; the arms and the spaces are exactly equal, and each arm has a triangular piece of wood *b d e*, (*fig. 12*.) screwed upon it, by four screws going through the arm into the wood, which is also kept firm and perpendicular to the face of the wheel, by a rib *f*, (*fig. 11*.) which projects from each arm, and is let into a groove cut in the wood. The wheels have sockets *g, g*, (*figs. 10 and 12*.) which are bored out with a very true cylindrical hole to receive the shaft or spindle *B B* of the rigger, which is turned in the lathe to fit the sockets without shake, yet at the same time allowing them to move backwards and forwards upon the axis *B B*. The wheels are put together upon the spindle facing each other, the wooden triangles of one wheel entering the space between the arms of the other, as is shewn in *figs. 10 and 12*; in this manner it is plain that the points, or rather plane, of intersection of the triangles *b d e* of each wheel, will form a circular groove to receive a rope, which groove can be increased in its diameter by advancing the wheels towards each other, or diminished by setting them farther apart, as in *fig. 10*. The wheels are prevented from turning on the spindle by means of a fillet, which is inserted partly into a groove cut in the axis, and partly in another groove made in the socket of the wheel. The wheels may be brought nearer together, or thrown farther apart, by two screws *h, h*, (*fig. 12*.) which have sockets in one wheel, and are tapped into the other: two equal cog-wheels *i, i*, are keyed fast upon the screws, and an intermediate cog-wheel *k*, placed loosely upon the main axis between them, causes both screws to turn at the same time. A more simple method of altering the diameter is by pushing the wheels together by hand, and fastening them to the axis by screws *e, e*, *fig. 10*.

Expansion

EXPANSION, in *Metaphysics*, expresses the idea we have of lasting or preserving distance, *i. e.* of distance, all the parts whereof exist together.

EXPANSION, from the Latin *expando*, in *Philosophy*, denotes the increment of surface or of bulk, of which natural bodies are susceptible. With respect to the expansion of surface, see the articles DUCTILITY and GOLD BEATING.

Bodies of every kind, as far as we are acquainted with them, are expanded in bulk by heat, and are contracted by cold; and to this law there are very few exceptions, which will be noticed in due time. The expansions, or the increments of bulk, are not exactly proportional to the increments of heat in the same body; nor are different bodies expanded alike by the like elevation of temperature. Thus, if a quantity of water be increased one inch in bulk, by the communication of ten degrees of heat, the communication of twice or thrice as much more heat will not cause it to expand two or three inches more. Also, if a rod of gold, and another similar rod of glass, be heated to the same degree, their increments of bulk, arising thereby, will not be equal, the gold expanding more than the glass.

Of the three principal states of natural bodies, *viz.* solids, liquids, and elastic fluids, the solids are expanded least; the liquids are expanded more than the solids, but the elastic fluids are expanded a vast deal more than the liquids. The knowledge of the precise quantities of these expansions of bodies is of great use in philosophy, in mechanics, and in other scientific subjects; hence no pains have been spared by philosophers to investigate and ascertain them; various instruments have been contrived for that purpose; innumerable experiments have been instituted;

and a great many useful results have been obtained. Of these results we shall now endeavour to give a regular and distinct account.

The instruments which have been contrived for the purpose of measuring the expansions of solids arising from an elevation of temperature, are called *pyrometers*. The objects which must be had in view in the construction of pyrometers, are to form a steady frame, wherein solids of a certain length may be applied either successively, or several of them at the same time, some contrivance by which those metallic bodies may be heated to any required degree, and a mechanism capable of measuring the increase of bulk which is caused by the heat; and this may be accomplished by means of multiplying wheels, by levers, by screws, by a microscopical micrometer, or otherwise. See PYROMETER.

Some of the first determinations of the expansion of bodies, that may be considered as being sufficiently accurate, were made by Mr. Ellicot with a pyrometer of his contrivance. Mr. Ellicot determined the proportional expansions of seven metallic bodies by the same elevation of temperature. They are as follows:

Gold.	Silver.	Brass.	Copper.	Iron.	Steel.	and Lead.
73.	103.	95.	89.	60.	56.	149.

Mr. Smeaton contrived a much better pyrometer, and with it he determined the expansions of several solids. Mr. De Luc also contrived a pyrometer of a peculiar construction; but Mr. Ramsden's pyrometer is superior to any other contrivance of the kind.

The following table shews, in parts of an inch, how much one foot length of different substances is expanded by 180° of heat, Fahrenheit's scale, between the freezing and the

boiling points of water. To the first seven substances, (which were examined in Mr. Ramsden's most accurate pyrometer,) there are added the expansions for a single degree of heat. The others were determined by Mr. Smeaton with his pyrometer.

Fahrenheit's Scale.

	By 1°	By 180°.
Standard brass scale, supposed to be Hamburg brass - - -	0.0001237	0.0222646
English plate brass in form of a rod - - - - -	0.0001262	0.0227136
English plate brass in form of a trough - - - - -	0.0001263	0.0227386
Steel rod - - - - -	0.0000763	0.0137368
Cast-iron prism - - - - -	0.0000740	0.0133126
Glass tube - - - - -	0.0000517	0.0093138
Solid glass rod - - - - -	0.0000539	0.0096944
White glass barometer tube - - - - -		0.0100
Martial regulus of antimony - - - - -		0.0130
Blistered steel - - - - -		0.0138
Hard steel - - - - -		0.0147
Iron - - - - -		0.0151
Bismuth - - - - -		0.0167
Copper hammered - - - - -		0.0204
Copper eight parts, with tin one part - - - - -		0.0218
Cast brass - - - - -		0.022
Brass sixteen parts, with tin one part - - - - -		0.0229
Brass wire - - - - -		0.0232
Speculum metal - - - - -		0.0232
Spelter folder, viz. brass two parts, zinc one - - - - -		0.0247
Fine pewter - - - - -		0.0274
Grain tin - - - - -		0.0298
Soft folder, viz. lead two parts, tin one - - - - -		0.0301
Zinc eight parts, with tin one, a little hammered - - - - -		0.0323
Lead - - - - -		0.0344
Zinc or spelter - - - - -		0.0353
Zinc hammered half an inch <i>per</i> foot - - - - -		0.0373

Iron, instead of being condensed into a smaller bulk, expands in its transition from a fluid into a solid state; so that a quantity of iron occupies more room in the solid form than it does in a fused state.

Dr. Wollaston, in order to form some estimate of the comparative rate of expansion of platina and palladium, says, "I rivetted together two thin plates of platina and palladium, and observing that the compound plate, when heated, became concave on the side of the platina; I ascertained that the expansion of palladium is in some degrees the greater of the two. By a similar mode of comparison I found that palladium expands considerably less than steel by heat." Phil. Transf. for 1805.

It must be remarked with respect to the expansion of glass, that sometimes glass tubes are extended more than solid glass rods: their dilatation, however, is not constant; for tubes of different diameters, or of different sorts of glass, are expanded differently by the like degrees of heat.

Wood is not expanded much longitudinally; that is, in the direction of its fibres, by heat, and this is particularly the case with deal and other straight-grained wood. Pro-

bably, upon the whole, the longitudinal expansion of wood is less than that of glass. It has been observed, (especially by Dr. Rittenhouse, Transf. of the American Phil. Society) that very dry and seasoned wood, if not exposed to a very high or to a very low temperature, will expand in length pretty regularly: otherwise its expansion by heat, and its contraction by cold, are very irregular: for they seem to depend partly upon the heat, and partly upon the moisture, which the wood acquires in certain circumstances, and is deprived of in others.

It is hardly necessary to mention, that the solids of the preceding table contract their dimensions by cooling as much as they are expanded by heating; thus, for instance, if a yard length of any particular metallic body, by being heated 100° above the actual temperature of the atmosphere, be lengthened one fiftieth part of an inch; afterwards, when cooled down to the temperature of the atmosphere, it will be found to have lost exactly that fiftieth part of an inch which it had acquired by heating.

From the experiments hitherto made on the expansions of solids by heat, no correspondence has been observed between the expansions and the quantities of caloric they are capable of absorbing. The fusibility of metals seems to coincide with the dilatations; platina, the least fusible of the metals, dilates the least; lead dilates most; and the most fusible glass is also the most dilatable. We may therefore conclude with Mr. Berthollet, that bodies are so much the more expandible, the less caloric they require to change their constitution from solid to liquid, and from liquid to gases or vapours.

There is a substance which expands when heated; but does not contract when cooled; and of this singular property Mr. Wedgwood availed himself for the construction of his ingenious thermometer for measuring the highest degrees of heat; viz. those degrees which exceed the scale of the mercurial thermometer. (See THERMOMETER.) The substance alluded to is the argillaceous earth or clay, and it appears that the above-mentioned property belongs, more or less, to argillaceous bodies of every kind. This property may at first sight appear to be an unaccountable exception from the general law: the difficulty, however, will vanish, if it be considered that bodies of the argillaceous genus contain a considerable quantity of water, and that the contraction of these bodies, when exposed to the action of a strong fire, is in great measure due to the escape of the water, and hence they do not contract by subsequent cooling.

The method of measuring the expansions of fluids is to inclose them in a certain vessel, and to measure that part of the cavity of the vessel, which is occupied by the fluid under trial, in different temperatures. It is evident that the substance of the vessel is likewise expanded by the heat, and of course the cavity of the vessel is enlarged. Therefore, when we find that the bulk of the fluid is increased, that increment is only the difference between the enlarged capacity of the vessel and the increased bulk of the fluid. This shews the necessity of forming those vessels of such substances as are least expandible by heat. Indeed glass is the substance which is universally used for such purposes, both on account of its little expandibility, and of its transparency; besides its having other useful properties. A glass vessel, filled to a certain degree with a liquid, for the purpose of shewing the expansions of that liquid in different temperatures, or for the purpose of shewing the temperature of the corresponding expansion of that liquid, is called a thermometer; viz. a measure of the temperature. See THERMOMETER.

The properest shape for a thermometer is that of a long

tube with a narrow bore, having a globular cavity at one end; which, familiarly speaking, may be called a globular glass bottle with a long and narrow neck. The globular cavity, and part of the tube of one of these vessels, is filled with the liquor whose expansion is to be examined, and the vessel is then heated, in consequence of which the liquor, which is contained in it, is expanded, and not being able to extend itself any other way, all the increment of bulk must be manifested in the tube; viz. the surface of the fluid will rise in the tube; or, if cooled, it will descend in it. If the same vessel of the above-mentioned shape be successively filled with different fluids, and with each fluid it be exposed to certain degrees of temperature, (which must be determined by an accurate thermometer,) the proportional expansions of the different fluids may thereby be ascertained. The same object may be obtained by filling several such vessels with the different fluids, that are to be examined, and heating or cooling them all at the same time; but in this case the corresponding capacities of the different vessels must be previously ascertained; which may be done by filling all the vessels with the same kind of fluid, and exposing them all to different degrees of temperature; so that the corresponding elevations of the fluid in the different vessels may be marked on the tubes. These vessels are afterwards emptied and filled again with the fluids, &c. Thus the proportional expansions of liquids may be determined; but when the actual or absolute increase of bulk is required, then the capacity of the vessel must be accurately gauged. This measurement of the capacity may be accomplished in the following manner. In the first place weigh the empty glass tube; secondly, fill part of the tube with a convenient fluid, (mercury, for instance, which is the fittest for such purposes); thirdly, measure the length of the tube which is occupied by the mercury, and weigh the instrument a second time; then, by subtracting this second weight from the former, you will have the weight of mercury which fills up a certain length of the cavity of the tube; fourthly, fill the bulb of the vessel entirely with mercury, and weigh the vessel a third time. This weight being subtracted from the first, viz. from that of the empty vessel, will leave the weight of the mercury in the bulb. Now, having the weight of the mercury in the bulb, as well as of that which fills a certain length of the tube, the ratio of the former to the latter may be easily determined by simple division. Also the absolute quantity in bulk of the former is obtained from the well known specific gravity of mercury, and from the weight of a cubic inch of distilled water, which (when the barometer is at 29.74 inches, and Fahrenheit's thermometer at 66°) is equal to 252.42 grains Troy; one pound Troy being equal to 5760 of those grains. An English cubic inch of mercury of the specific gravity 13.6 weighs 3443.2 English grains. Instead of mercury, some other fluid may be employed for this purpose; but not so conveniently as mercury. The expansions of a fluid, which are caused by different degrees of heat, may likewise be determined by ascertaining the specific gravity of that fluid in different temperatures; for the specific gravity decreases in proportion as the fluid is expanded, and *vice versa*; but this method is not capable of as much accuracy as the former.

Liquids differ from each other in regard to their expansibility; some expanding more than others. Also the expansions of the same liquid by equal degrees of heat are not quite regular; and it has been observed that this irregularity is greater when they approach the state of vapour. Upon the whole, mercury has been found to be expanded by

heat more regularly than any other fluid; yet its increments of bulk are not perfectly regular. Mr. De Luc, with great care and patience, has endeavoured to ascertain the real expansibility of mercury, or rather the real quantities of heat that are required for expanding mercury arithmetically, viz. by equal augmentations. These are expressed in the following table, the first column of which contains the degrees of Reaumur's scale, from five to five, which are equal parts; the second shews the real quantities of heat which are required to raise the mercury to the corresponding degrees, where x is a fixt but unknown quantity; and the third column shews the differences of those quantities. De Luc's Recher. sur les Modif. de la Atmosph. 1772, p. 309.

	Mercurial Thermom.	Real quantities of heat.	Real differences of heat corresponding to the variations of the Mercury in the thermom. from 5 to 5 degrees.
Point of boil. water	80°	$x + 80.00$	—4.72
	75	$x + 75.28$	—4.72
	70	$x + 70.56$	—4.79
	65	$x + 65.77$	—4.81
	60	$x + 60.96$	—4.81
	55	$x + 56.15$	—4.89
	50	$x + 51.26$	—4.89
	45	$x + 46.37$	—4.97
	40	$x + 41.40$	—5.00
	35	$x + 36.40$	—5.08
	30	$x + 31.32$	—5.10
	25	$x + 26.22$	—5.10
	20	$x + 21.12$	—5.18
	15	$x + 15.94$	—5.20
	10	$x + 10.74$	—5.31
	5	$x + 5.43$	—5.43
Point of melt. ice	0	x	

From the third column it appears, that the differences of heat requisite to make equal and progressive additions to the bulk of the mercury, though not exactly equal, yet are not very far from the ratio of equality. If the bulk of a quantity of mercury, at the temperature of 32° Fahrenheit's scale, be conceived to be divided into 100,000 equal parts, and then be heated as high as the temperature of boiling water; (viz. 212°) its bulk will thereby be increased by 1836 of those parts.

The expansion of water is attended with a singular deviation from the general law; viz. this fluid is expanded by heat from about the 40th degree of Fahrenheit's thermometer upwards; but below 40° its bulk is expanded by a farther decrease of heat, or increase of cold; and in fact ice is lighter than water, so as to float upon it; the specific gravity of ice being to that of water nearly as 7 to 8. The bulk of ice is to that of the water, when the ice is melted, as 9 to 8 very nearly. The bulk of water, from its most contracted state at the temperature of 40°, increases continually; but that increase is not very regular; for instance, the increase of bulk from 180° to 212°, is considerably greater than from 40° to 72°. If the bulk of water at 40° be called 1, its bulk at 212 will be 1.04785. Beyond that degree of heat water becomes vapour; viz. an elastic fluid, and the formation of this elastic fluid on the sides of the vessel within the water, forms the bubbles, the escape

of which constitutes the boiling. The bulk of steam at the boiling point is somewhat less than 1800 times the bulk of the water from which it originated.

The expansion of freezing water is not owing to the extrication of air; for water deprived of air expands like other water in freezing. Mr. Mairan attributes it to a strong tendency the particles of water have to arrange themselves into ranks and lines, which cross one another at angles of 65° and 120°. This tendency seems to begin at the temperature of 40°. The expansion of freezing water has a prodigious force. It is owing to this that in hard frosts timber is burst, plaster is removed from walls, and even iron mortar shells filled with water, and accurately stopped, have been burst by the freezing of the water.

This singular property of water, viz. its expanding from the temperature of 40° downwards, so as to become lighter and lighter in proportion as it becomes colder and colder, is a most striking instance of the wisdom of the Creator, and is a property of immense consequence to the very existence of animals and vegetables. A quantity of water is indispensably necessary to animals and to vegetables at all times of the year. In winter, when the cold air freezes the surface of the water, that effect seldom penetrates lower than two or three feet. Below that depth the water continues fluid, and the crust of ice itself contributes to preserve its fluidity. The heat of the earth, which has been acquired during the summer, undoubtedly prevents the formation of ice below a certain depth. But if water in cooling had continued to increase in specific gravity, and had ice been actually heavier than water, the heat of the earth would not have been sufficient to prevent the total freezing of all the waters of lakes, seas, rivers, &c. "For," says count Rumford, "as the particles of water on being cooled at the surface would, in consequence of the increase of their specific gravity, on parting with a portion of their heat, immediately descend to the bottom, the greatest part of the heat accumulated during the summer in the earth, on which the water reposes, would be carried off and lost before the water began to freeze; and when ice was once formed, its thickness would increase with great rapidity, and would continue increasing during the whole winter; and it seems very probable that in climates which are now temperate, the water in the large lakes would be frozen to such a depth in the course of a severe winter, that the heat of the ensuing summer would not be sufficient to thaw them; and should this once happen, the following winter would hardly fail to change the whole mass of its waters to one solid body of ice, which never more could recover its liquid form, but must remain immoveable till the end of time." (7th Essay.)

The following table shews the expansions of the principal liquids that have been submitted to such experiments, according to Mr. De Luc's observations. With respect to this table it must be understood that different thermometers (each being filled with a particular fluid, such as is mentioned at the top of each column, and each being divided into 80 equal parts between the freezing and the boiling points of water) are placed with their bulbs in the same vessel full of water, and that the water is gradually heated. Then when the mercurial thermometer stands at 5°, 10°, 15°, &c. the surfaces of the fluids in the other thermometers will be found at the degrees which stand on the same levels; for instance, when the mercurial thermometer stands at 40°, the water thermometer will be found to stand at 20°.5, the spirit thermometer will be found to stand at 35°, the oil thermometer at 35°.2, &c.

	Mercury.	Water	Water saturated with salt.	Alcohol.	Alcohol 3 parts, water 1.	Alcohol and water equal parts.	Alcohol 1 part, water 3.	Oil of olives.
Boiling water	80°	80.0	80.0	80.0	80.0	80.0	80.0	80.0
	75	71.0	74.1	73.8	73.7	73.2	71.6	74.6
	70	62.0	68.4	67.6	67.5	66.7	62.9	69.4
	65	53.5	62.6	61.5	61.5	60.6	55.2	64.4
	60	45.8	57.1	55.5	55.8	54.8	47.7	59.3
	55	38.5	51.7	50.3	50.2	49.1	40.6	54.2
	50	32.0	46.6	45.1	44.9	43.6	34.4	49.2
	45	26.1	41.2	40.0	39.7	38.4	28.4	44.0
	40	20.5	36.3	35.0	34.8	33.3	23.0	39.2
	35	15.9	31.3	30.1	29.8	28.4	18.0	34.2
	30	11.2	26.5	25.5	25.2	23.9	13.5	29.3
	25	7.3	21.9	20.9	20.7	19.4	9.4	24.3
	20	4.1	17.3	16.5	16.2	15.3	6.1	19.3
	15	1.6	12.8	12.0	11.8	11.1	3.4	14.4
	10	0.2	8.4	7.9	7.7	7.1	1.4	9.5
Freezing	5	0.4	4.2	3.9	3.8	3.4	0.1	4.7
	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	5		4.1					
	10		8.0					

The expansions of elastic fluids, such as common air, the gases, and vapours, are more difficultly ascertained; for the expansions of those fluids are occasioned by a diminution of pressure, as well as by an increase of temperature; and it is difficult to subject any of those fluids to the action of one of these causes only at a time, in order that the effect of each may be duly estimated.

When common air is acted upon by pressure only, independent of any alteration of temperature, its bulk is found to increase and to decrease in the inverse proportion of the pressure; thus, the air close to the surface of the earth is compressed into the bulk which we experience, by the superincumbent atmosphere. If that pressure be increased, the bulk of the lower air will be contracted, which is manifested by an augmentation of its weight; if that pressure be diminished, the bulk of the lower air will be increased, as is manifested by a diminution of its weight. And this expansion and contraction of the air is exactly but inversely proportional to the pressure; so that a double pressure will compress it into half the space, a treble pressure into one third of the original space, &c. The same thing, *mutatis mutandis*, may be said of the removal of pressure, and of the expansion thereby arising. This elasticity of the air has not been found to be impaired by a long continuance of the pressure; for air has been left during several years very much compressed in proper vessels, wherein there was nothing that could have a chemical action upon it; and afterwards on removing the unusual pressure, and replacing it in the same temperature, the air has been found to recover its original bulk. It is not known how far a quantity of air may be expanded by removing the pressure, nor how much it may be compressed by increasing the pressure; for no experiments have as yet been able to ascertain either limit.

The instrument, in which the expansion of air is tried, has been called *manometer*, (which see.) It is a sort of large air thermometer, consisting of a tube five or six feet long, having a bulb at one end, and being open at the other end. The bore of the tube is about a 20th of an inch in diameter. A small quantity of quicksilver is placed in some

part of the cavity of the tube, and the expansion of the air in the bulb, when heated, forces the quicksilver to move towards the open end of the tube. The degree of heat to which the manometer is exposed is measured by means of a thermometer; the quantity of expansion of the air is measured by gauging the manometer, and making marks on the tube, which may indicate parts of the cavity of the tube that are proportional to the capacity of the manometer; as for instance 100dths, 1000dths, &c. By placing the manometer horizontal or vertical, either with the bulb downwards or upwards, the air in it may either be left of the natural density, or it may be condensed, or, lastly, it may be rarefied; for when the manometer stands horizontal, the quicksilver in the tube does not press upon the air in the bulb, nor on that of the atmosphere; when the bulb is downwards, the quicksilver presses upon the air of the manometer, and when the bulb is upwards, the quicksilver presses against, and counteracts, in some measure, the gravity of the atmosphere. Hence this pressure, and this expansion of the air within the manometer, may be increased to any required degree by increasing the quantity of quicksilver within the tube; and thus the expansibility of common, or of condensed, or of rarefied air, may be tried. The expansion of air, by the same degrees of heat, differs according to its density, and to the quantity of moisture it contains; nor are the increments of its bulk proportional to the degrees of temperature.

It appears from Col. Roy's very numerous experiments (Phil. Transf. vol. 67th) that 1000 parts of air, of the density of the common atmosphere, at 0° of heat, become 1484.21 at 212° ; viz. are expanded 484.21, by 212° of heat.

1000 parts of air loaded with $2\frac{1}{2}$ atmospheres, are expanded 434 of those parts, by 212° of heat.

1000 parts of air pressed only with $\frac{1}{3}$ ths of an atmosphere, are expanded nearly 484 of those parts by 212° of heat.

1000 parts of air pressed with $\frac{1}{3}$ th of an atmosphere, are expanded about 141 parts by 180° of heat; viz. from the freezing to the boiling point of water.

"From these last experiments," Col. Roy says, "it would seem that the particles of air may be so far removed from each other, by the diminution of pressure, as to lose a very great part of their elastic force."

The above-mentioned expansions of air are by no means regular: viz. they are not proportional to the number of the degrees of heat. The maximum of expansion takes place between 52° and 72° : and the minimum is constantly at the boiling point of water. Moist air expands a great deal more than dry air, especially when it approaches the boiling point of water; so that between 192° , and 212° , moist air expands about eight, or nine, times as much as dry air in similar circumstances.

The expansions of gases may be tried and determined in the same manner as the expansion of common air. From a long series of experiments Messrs. Guyton and Prieur deduced a dilatation peculiar to each gas; but Mr. Guy-Lussac has shewn, that all gases, without exception, possess the same expansibility at the same degree of temperature, and that the presence of water in gases occasioned the errors into which his predecessors had fallen. He is led to conclude from his experiments made on gases reduced to the utmost degree of dryness, that 100 parts of each of the permanent gases acquire an increase of $\frac{1}{17}$ by every degree of the thermometer from 0° to 80° Reaumur's scale. Vapours, he also thinks, follow the same laws of dilatation as gases, provided the temperature be sufficiently elevated to keep them in the elastic state. Therefore, Mr. Chaptal says, it may be laid

down as a principle, that gases and vapours are equally dilat-able, and equally compressible; but it will be necessary to be more particular with respect to the expansibility of the vapour of water, upon the elasticity of which numerous natural phenomena, and the action of several important machines, depend.

Mr. Schmidt also made a series of experiments upon the expansibility of air, made as dry as possible by exposure to hot potash. He found the expansion of a quantity of air which measured one inch at the freezing point, viz. at the temperature of 0° Reaumur's thermometer, to expand as be-
low.

Degrees of Reaumur.	Expansion of one inch.
1	0.0044675
4	0.0178700
8	0.035740
12	0.0536100
16	0.0714800
20	0.0893500
24	0.1072200
28	0.1250979
32	0.1429600
36	0.1608300
40	0.1787000

This table also shews, by its differing from the results of D'Amontons, De Luc, Lambert, Schuckburgh, Berthollet, and others, that those gentlemen operated upon air more or less charged with moisture. They also took the barometers at different altitudes. In Mr. Schmidt's experiments the barometer was taken at 29,841 English inches. These variations of the rates of expansibility of moist air, saturated at different temperatures, Schmidt attributes to the variations of the degrees of affinity between air and vapour.

Water heated to the 212^{th} degree of Fahrenheit's thermometer (or thereabout, for the different gravity of the atmosphere occasions a considerable difference) overcomes the ordinary pressure of the atmosphere and becomes steam, an elastic substance, the bulk of which at that point is somewhat less than 1800 times the bulk of the water from which it originated. Beyond that point vapour is expandible in a most astonishing degree; for 0° more of heat (viz. the temperature of 242°) will double the elastic force of steam; 30° more added to that (viz. the temperature of 272°) will render the elastic force of steam nearly equal to four atmospheres; and so forth. This immense expansibility of steam, when the heat which produces it is quickly supplied, is capable of producing prodigious effects. When water is caused to boil in a vessel upon a common fire, the heat which is communicated cannot convert all the water at once into steam; but if the quantity of water be small in proportion to the heat which can be communicated in a given time, then the conversion of water into steam is quickened to any degree, and it may be rendered instantaneous; in which case it produces a sudden and violent expansion, or an explosion. A drop of rain in boiling linseed oil, falls to the bottom, is instantly converted into vapour, and occasions dangerous consequences. "It has sometimes," Dr. Black says in his Chemical Lectures, "happened that a person, by carelessly spitting into a copper foundry, has occasioned an explosion that destroyed the whole building." Count Rumford attributes the vast force of gun-powder to the sudden conversion into vapour of that quantity of water which naturally enters into the composition of that powder; it being a component of the nitre. Phil. Transf. for 1797.

Water at the temperature of 212° is converted entirely into steam, or rather, under the ordinary pressure of the atmosphere, water cannot be heated higher than 212° ; but water is gradually converted into steam or vapour at a much lower temperature. Mr. Pictet instituted a series of experiments on the elasticity of pure vapour in low temperatures. He found that a grain of warm water in vacuo evaporates in forty minutes in the temperature of 38° Fahr. under a receiver containing 1452 English cubic inches, but that it did not diffuse itself equally in less than six hours and then raised the hygrometer from 17° to 60° , that is, 43° ; and during this whole time the cold under the receiver was constantly decreasing, though slowly: which decrease undoubtedly contributed to the diffusion of the vapour. *Essais de Physique*, p. 157.

The best, or most extensive experiments upon the expansive force of the steam of water, and of the steam of alcohol, were made by the Chev. de Bettancourt; and are related by Prony in the second volume of his "*Architecture Hydraulique*;" from which the following compendious sketch is derived.

The fluid with which the experiments were made was confined in a very strong copper boiler, being eight inches at its greatest diameter, and fourteen inches in height. The upper part of it was closed by a cover made of copper, through which passed three tubes. The first served to introduce the fluid into the boiler, and could be closed by means of a screw. The second was occupied by a thermometer, having its ball about two inches above the bottom of the boiler, and the scale, which was on the outside, contained from 0° to 110° of Reaumur. To the third was adapted a bent barometer tube, having two lines of internal diameter; the ascending branch of which was 110 inches in length. By means of a lateral cock a communication was established between the boiler and an air pump, which served to make a vacuum before the fire was kindled in the furnace below the apparatus. This circumstance of evaporation in a vacuum forms an essential difference between the experiments of Bettancourt and those made before by Ziegler, and renders them applicable to the theory of the steam-engine, where the vapour acts in a space freed from air.

A vacuum having been made in the boiler, the mercury brought as nearly as possible to a level in the two branches of the barometric tube, and the thermometer reduced to zero by means of ice, the ice was removed, and a fire was kindled, which was excited gently and with much equality, that the thermometer passed over about a degree per minute. One person then stood by to observe the barometer, and another to observe the thermometer, and each kept a register from degree to degree of the pressure and corresponding temperatures; the pressure being expressed by the height, in French inches, of the columns of mercury, which rose above the level in the long branch of the barometer.

These observations of the expansive force of the steam of water furnish 110 results, proceeding from degree to degree of the thermometer, and beginning at zero. These results are contained in the following table, where the degrees of pressure are expressed in French inches of perpendicular height of mercury, and the temperature is denoted according to Reaumur's scale. The experiments on the expansive force of the steam of alcohol were made by the like process, and with the same apparatus.

TABLE of the Expansive Force of the steam of Water and of Alcohol.

Temperature.	Pressure.		Temperature.	Pressure.		Temperature.	Pressure.	
	Water.	Alcohol.		Water.	Alcohol.		Water.	Alcohol.
0	0.00	0.00	37	2.45	5.55	74	20.60	48.10
1	0.00	0.00	38	2.57	6.00	75	21.75	50.20
2	0.00	0.00	39	2.75	6.45	76	22.90	52.60
3	0.00	0.05	40	2.92	6.90	77	24.15	55.30
4	0.02	0.09	41	3.10	7.35	78	25.50	57.90
5	0.02	0.12	42	3.27	7.82	79	26.67	61.00
6	0.05	0.18	43	3.47	8.37	80	28.00	63.80
7	0.07	0.25	44	3.70	8.92	81	29.60	66.90
8	0.10	0.32	45	3.95	9.48	82	31.30	69.80
9	0.12	0.38	46	4.25	10.15	83	33.00	73.40
10	0.15	0.45	47	4.45	10.80	84	34.60	76.90
11	0.18	0.50	48	4.75	11.5	85	36.45	79.60
12	0.22	0.62	49	5.00	12.20	86	38.10	83.60
13	0.27	0.72	50	5.35	12.35	87	40.00	87.10
14	0.30	0.82	51	5.70	13.75	88	42.20	90.80
15	0.35	0.93	52	6.05	14.60	89	44.30	95.00
16	0.40	1.02	53	6.50	15.50	90	46.40	98.00
17	0.45	1.12	54	6.90	16.40	91	48.40	
18	0.52	1.25	55	7.32	17.65	92	50.50	
19	0.58	1.38	56	7.85	18.85	93	53.00	
20	0.65	1.52	57	8.40	20.00	94	55.30	
21	0.75	1.65	58	8.85	21.20	95	57.80	
22	0.82	1.80	59	9.35	22.30	96	60.50	
23	0.90	1.95	60	9.95	23.70	97	63.40	
24	0.97	2.10	61	10.40	24.80	98	66.20	
25	1.05	2.32	62	11.00	26.10	99	69.00	
26	1.12	2.52	63	11.70	27.40	100	71.80	
27	1.22	2.75	64	12.40	28.90	101	75.00	
28	1.32	2.95	65	13.20	30.60	102	78.20	
29	1.42	3.20	66	13.80	32.00	103	81.00	
30	1.52	3.40	67	14.50	33.50	104	84.00	
31	1.65	3.70	68	15.25	35.10	105	86.80	
32	1.78	4.00	69	16.10	37.20	106	89.00	
33	1.90	4.30	70	16.90	39.40	107	91.30	
34	2.00	4.60	71	17.80	41.30	108	93.50	
35	2.15	4.95	72	18.70	43.50	109	95.60	
36	2.27	5.28	73	19.50	46.00	110	98.00	

The expansive force of the steam of water has also been determined by Mr. Schmidt, with all the accuracy that the experiments seem to admit of: but the results which he has not stated for every degree of the thermometer, do not agree exactly with those of Bettancourt. We deem it therefore necessary to subjoin those results in the following short table, wherein the temperature is expressed in degrees of Reaumur's thermometer, as in the preceding table, and the expansive force in French inches of perpendicular altitude of mercury.

TABLE of the Expansive Force, of the pure vapour of Water, according to Mr. Schmidt.

Temperature.	Expansive Force.	Temperature.	Expansive Force.
0	0.0	22	1.01
5	0.11	25	1.30
6	0.15	27	1.42
10	0.28	30	1.93
12	0.38	33	2.23
13	0.44	35	2.68
15	0.55	37	3.20
16	0.61	39	3.40
18	0.76	40	3.64
20	0.90	80	28.00

Mr. Dakon has likewise endeavoured to determine the expansive force of the vapour of water; but the results of his experiments nearly coincide with those of the preceding tables, which supercedes the necessity of stating them in the present article. See EVAPORATION.

From a careful examination of all the experiments made on this subject, Dr. Young has deduced a formula by which the expansive force of steam may be determined for any degree of the thermometer, pretty near the real results of the experiments. The formula is as follows:

Let f denote the temperature according to Fahrenheit's thermometer, and e the number of inches in perpendicular height of mercury, which the steam is capable of supporting; then the formula is $e = .1781 (1 + .006 f)^2$.

The reader might perhaps expect to find in the present article the particulars relative to the expansions of heat, and of electricity; but the uncertain natures of the fluids, to which the effects of heat and of electricity are attributed, besides other considerations, oblige us to refer him to other parts of this Cyclopædia. See HEAT, CALORIC, and the articles belonging to electricity.

Dr. Gregory, in his Astron. p. 407, proves, that a globe of our air, of an inch diameter, if it were removed to the distance of a semidiameter of the earth, would expand itself so as to fill all the planetary region as far as, nay, far beyond the sphere of Saturn. See AIR.

Felting

FELTING, in the *Manufactures*, denotes the operation by which the fur, hair, and wool of animals are wrought into a species of cloth, without either spinning or weaving. A hatter separates the hairs from each other by striking the wool with the string of his bow, thus causing them to spring up in the air, and they then fall in every direction on the table, spread and distributed in small flocks, which the workman covers with a cloth, slightly moistened; pressing it with his hands, and moving the hairs backwards and forwards in different directions. In this manner the different fibres are brought against each other, and their points of contact considerably multiplied; and the agitation gives each hair a progressive motion towards the root, in consequence of which the hairs become twisted together. As the mass becomes compact, the pressure should be increased, in order to keep up the progressive motion and twisting of the hairs, which is thus performed with greater difficulty. The various fibres of the materials being thus by a gradual pressure in different directions made to interweave and cross each other, form a piece of stuff of a soft and spongy texture; upon this first piece is placed another, formed in the same manner, and sometimes a third or fourth, according

to the nature of the materials, and the intended thickness and consistence of the work. These different pieces are successively brought together, and disposed in a form suitable to the article which is to be fabricated; and in order to effect the cohesion, the operator uses a number of pressures and alternate motions in different directions, during which he preserves the suppleness and flexibility of the material by slight aspersions of water. The next operation is *fulling*, which see. The hair intended for the manufacturing of hats is always cut off with a sharp instrument, and not pulled up by the roots; because the bulb of the hair, which would come out with it in the latter case, would render the end which was fixed in the skin very obtuse, and nearly destroy its disposition to unite with the adjacent hairs. The hairs should not be straight like needles, for then there would be no compactness in the stuff. The fibres of wool having naturally a crooked form, that substance is well adapted to the operation of felting. The hair of beavers, rabbits, hares, &c. being straight, cannot be used in felting, till it has been prepared for the purpose. See HAT.

Fermentation

FERMENTATION. The important process by which saccharine solutions are converted into intoxicating liquors, is one of the most complicated in chemistry, and the precise cause of this change is as yet very imperfectly known. In the present article we shall notice the conditions requisite to fermentation, the appearances that occur during the process, and the essential product of it, reserving for the articles *SPIRITS*, *Distilled*, and *WINE*, some further particulars.

The only two substances indispensably requisite to the formation of a fermentable liquor are water and sugar.

No vegetable juice will ferment that is not sensibly sweet, and from which a portion of sugar may not be extracted by chemical means. The strength of vinous liquors (other circumstances being the same) is in direct proportion to the quantity of sugar contained in them before fermentation. The addition of sugar to the weakly fermentable juices will enable them to produce a strong full-bodied liquor, and the very essence of this process is the disappearance of the sugar, and the consequent production of alcohol.

With regard to the water, it does not appear how far this is an active ingredient in vinous fermentation, though it is fully ascertained that a particular degree of dilution is necessary to this process: this consistence exists naturally in the juice of grapes, in the saccharine sap of many trees, and of other spontaneously fermentable liquors; and if these very liquors be deprived by gentle evaporation of a considerable portion of their water, the residue will not ferment till the requisite consistence is restored by the addition of a fresh portion of water. On the other hand, if a saccharine mucilage is too dilute, the fermentation is very languid and imperfect.

But pure sugar and water alone will not ferment, and therefore some other substance is also requisite. To this point the attention of chemists has been often directed, but hitherto with but little success; indeed, the general result of the experiments that have been made is, that several substances, very different in their other properties, will answer almost equally well as a ferment. Must, or the recent juice of

the grape, contains, beside sugar and water, a quantity of vegetable acid, chiefly the tartareous, and one or more substances obscurely described under the names of mucilage and extract. Each of these is requisite to the fermentation of must; for if any one is abstracted the process will not take place. A warm temperature is also requisite to fermentation. This varies according to the natural fermentability of the materials, and their bulk. Thus, grape-juice will readily begin to ferment at the temperature of about 60°, and the process is strong and vehement at 70° or 80°. The expressed juice of the sugar-cane is so excessively prone to fermentation, that in the climate of the West Indies the process would begin in ten minutes, or a quarter of an hour; and hence, as fermentation is the destruction of the sugar, it is necessary, in making sugar, to counteract this tendency in the expressed juice as speedily as possible, which is effected merely by bringing it to a scalding heat. A low temperature, as that of freezing water, is equally efficacious in preventing or arresting the progress of fermentation, so that all domestic processes of this kind are performed within doors, or near a fire, and in the large way chilling must be particularly avoided; but as the act of fermentation produces a considerable heat, the liquor within the vessel being several degrees warmer than the surrounding air, large masses are of course less affected by the external cold, and will ferment at a lower temperature.

The first signs of fermentation are, a gentle intestine motion, the rising of small bubbles to the top of the liquor, and a whitish turbid appearance. This is soon followed by the collection of a froth, or head, consisting of a multitude of air-bubbles entangled in the liquor, which, as the process advances, rise slowly to a considerable height, forming a white dense permanent froth. A very large portion of the gas also escapes, which has a strong, penetrating, agreeable, vinous odour. The temperature of the liquor at the same time increases to several degrees above that of the external air, and continues so during the whole of the process.

Sooner or later these appearances gradually subside; the head of the foam settles into a dense froth, and on turning it aside, the liquor beneath appears much clearer and nearly at rest, having deposited a copious sediment, and from being viscid and saccharine is now become vinous, intoxicating, thinner, and of less specific gravity.

The process of fermentation, however, does not terminate suddenly, but goes off very gradually, the liquor continuing to work or throw up foam, to clarify, to attenuate, and more completely to lose its sugar, which at last can no longer be discerned by the taste, or detected by chemical analysis. The vinous liquor, when complete, if of sufficient strength and well fermented, will now keep for a great length of time in vessels secured from the air, and undergoes comparatively little farther alteration, except in becoming more perfectly limpid by the deposition of an additional quantity of sediment.

The gas of fermenting liquors has been long known to consist for the most part of carbonic acid; it will, therefore, extinguish a candle, destroy animal life, convert caustic alkalis into alkaline carbonates, and the like. But, beside the carbonic acid, it has been proved by Scheele to hold in solution a sensible quantity of alcohol, and Proust has detected in it a portion of azot. Mr. Collier (Manchester Trans.) has further shewn that in this gas are contained all the requisites for vinous fermentation. He passed the whole of the gas from a ninety gallon fermenting tun into a cask of water, and divided the liquor thus impregnated into three parts, of which one being immediately distilled, afforded a small quantity of alcohol; to the second was added some yeast, by which a new fermentation was excited, and the subsequent product of distilled spirit was nearly doubled, and the third being suffered to ferment a longer time, produced some vinegar.

The attenuation of liquors, or the diminution of their specific gravity by fermentation, is very striking. This is shewn by the hydrometer, which swims much deeper in fermented liquor than in the same materials before fermentation. Much of this attenuation is, doubtless, owing to the destruction of the sugar, which, dissolved in water, adds to its density, and to the consequent production of alcohol, which, on the contrary, by mixture with water, diminishes the density of the compound. The extract, or mucilage, also appears to be in some degree destroyed by fermentation, for the gelatinous consistence of thick liquors is much lessened by this process: the destruction of this principle, however, is by no means so complete as of the sugar, many of the full-bodied ales, for example, retaining much of their original clamminess and gelatinous density even after having undergone a very perfect fermentation.

It has been doubted whether the alcohol of vinous liquors exists in them ready formed, or in some intermediate state, requiring the boiling heat of distillation for its complete development. It is not easy to fix upon an unexceptionable mode of deciding this question. It has been argued by Fabbroni, in favour of alcohol being a product, and not an educt from wine, that wine cannot be again formed by adding the distilled alcohol to the residue left behind in the retort: he also affirms, that if a small portion of alcohol is added to wine, it may be separated again almost entirely by carbonate of potash, but that this salt will not separate any alcohol from wine in its natural state. This last fact, however, only shews that the union of the alcoholic with the other parts of the wine, is too strong to be broken by simple affinity, without the assistance of heat; and, as to the former, it is highly probable that the boiling heat operates some change on the other constituents of wine, the effect of

which cannot be done away by the mere return of the spirit that has been driven off. This opinion, therefore, though by no means improbable, requires further confirmation.

The production of alcohol seems to be one of the last effects, or the completion of the process of fermentation; for if the liquor is distilled while yet in a state of high fermentation, it will not yield a drop of alcohol.

The atmospheric air seems to have no share whatever in vinous fermentation, for it will take place full as well inclosed as in open vessels, provided space is allowed for the great expansion of the materials, and the copious production of gas. Indeed Mr. Collier found, by direct experiment, that more spirit is procured by close than by open fermentation. In three separate experiments, in each of which an equal quantity of wort and yeast were fermented, under circumstances precisely similar, with the single exception, that in one the vessel was open, and in the other closed, (the gas having no exit but through a tube dipping in water,) he found, on distilling each fermented liquor, and drawing off the same bulk of spirit from each, that that from the close vessel was constantly of less specific gravity, and, therefore, richer in alcohol than the other. Where the spirit from the open vessel was 74 degrees below proof, that from the close vessel was 56 degrees; where the former was 83, the latter was 65; and where it was 103, the other was 93.

The theory of vinous fermentation is still involved in great difficulty, on account of the very compound nature of the substances employed, and their great tendency to decomposition in various ways and proportions.

The results of Lavoisier's experiments should not pass unnoticed, though it is obvious that much too great simplicity is attempted in the explanation of a process which every circumstance shews to be very complicated. The simple point to which the experiments of this able inquirer tend, is (setting aside all other agents) to explain how sugar becomes converted into carbonic acid and alcohol, which, after all, is the characteristic phenomenon of vinous fermentation.

The entire products of sugar, yeast, and water, fermented in close vessels, are stated to be carbonic acid, alcohol, and water, together with a small portion of acetic acid, and from these facts the following theory is deduced. Sugar is composed of eight parts hydrogen, 64 oxygen, and 28 carbon, and the process of fermentation effects a change merely in the arrangement of the constituent parts of the sugar, converting one portion into carbonic acid, and the other into alcohol; and hence (as carbonic acid contains only carbon, with a large proportion of oxygen) the portion which is left must contain all the hydrogen, part of the carbon, and a very small proportion of oxygen: or, in other words, by this new arrangement of the ingredients of the sugar, one portion, namely, the carbonic acid, is totally deprived of hydrogen, and overloaded with oxygen, while the other portion, namely, the alcohol, abounds in hydrogen, and is deficient in oxygen; the carbon being divided between the new products in nearly an equal proportion with regard to their respective quantities.

No theory more plausible than the above has, perhaps, hitherto been offered to the general phenomenon of vinous fermentation, though it is very defective in many essential parts, and even does not correspond with the alleged composition of alcohol, given by the same chemist in another part of his enquiries.

The great question remaining for future enquirers to determine is, what the substance or circumstance is, which disposes sugar to ferment; for it has been proved that sugar will not of itself begin this spontaneous change into carbonic

acid and alcohol; though, when once begun, the process will probably go on without further assistance.

It has been already mentioned, that both extractive matter and an acid are present in every known instance of vinous fermentation; and, for any thing that appears to the contrary, both of them are necessary, though the requisite quantity of each is very small compared to the sugar: therefore the strength or body of the fermented liquor is in direct proportion to the quantity of sugar alone, and there is good reason to suppose that the extractive matter and the acid are only accessory ingredients, though still essential, as being those without which the vinous decomposition of sugar cannot be effected.

It has been supposed that it is the *vegeto-animal* extract, as it has been called, which exists in the fermentable juices of vegetables, that causes the first change in the sugar. The precise nature of this *vegeto-animal* matter is not very well known: it may be supposed to be similar to the gluten of wheat, but intimately combined with the saccharine mucilage, and hence extremely susceptible of spontaneous change. The chief, if not the only, proof of its existence in many of these combinations, is the production of a quantity of ammonia during its decomposition by heat, which alkali is almost always formed by the action of fire, and indicates in the substance which yields it the presence of azot.

Some of the commonest fermenting ingredients, as the sweet infusion of malt, technically called wort, it is well known, will hardly enter into fermentation without the addition of yeast; and hence chemists have sought in this substance for the principle which gives the first impulse to the fermentation of sugar.

The analysis of yeast presents a vast variety of ingredients, the chief of which are the carbonic, acetic, and malic acids, mucilage, sugar, and gluten. Of these the latter is in the largest proportion, which would seem to give much weight to the opinion of the great share which the azotic ingredient has in inducing fermentation.

Yet Mr. Henry found by a series of very interesting experiments, that malt infusion might be made to enter into complete fermentation by impregnating it with carbonic acid prepared from chalk and sulphuric acid, and the liquor thus fermented gave a yeast which made perfect bread, gave alcohol by distillation, and vinegar by further keeping. The wort itself undoubtedly contained all the ingredients of yeast, since this substance was produced during the fermentation, but the experiment is decisive to prove that no addition of azotic extract is required to begin fermentation in materials naturally fermentable, though, when once begun, the yeast, as fast as it was produced, must have assisted in the fermentation then going on. The evidence for the necessity of an acid to begin fermentation is therefore more decisive, but it is still doubtful whether any particular one is required, or whether there are not several which will answer the purpose. In Mr. Henry's experiments the acid employed was the carbonic, and, from the arrangement of the apparatus, probably a small portion of sulphuric was also carried in along with it. But in grape juice there is no proof of the existence of carbonic acid ready formed, though the tartaric, malic, and other vegetable acids contain within themselves the ingredients of carbonic acid, and are chiefly and ultimately resolvable into this acid. Yeast will even induce fermentation after it is pressed and dried into solid cakes, (a practice not uncommon, as it will keep for a great length of time in this form,) but after this operation it can hardly contain any carbonic acid ready formed, though with abundant tendency to produce it by

the first mutual action of its constituent parts. Many interesting enquiries therefore remain to be carried on before we can have a full and satisfactory theory of the important process of vinous fermentation.

FERMENTATION, Acetous. See *Acetous Acid*, and *VINEGAR*.

FERMENTATION, Putrid. See *PUTREFACTION*.

FERMENTATION, Bituminous, in *Geology*, denotes a particular change, which, according to the opinion of Mr. James Parkinson, (*Organic Remains*, vol. i. p. 184.) "is peculiar to vegetable matter placed in such situations, as not only exclude the external air, and secure the presence of moisture, but prevent the escape of the more volatile principles, and which terminates in the formation of those substances called bitumens." This author, after giving a concise, but luminous account of the *saccharine*, the *vinous*, the *acetic*, and the *putrid* fermentation, to which most vegetable substances are progressively liable, by the modified admission of atmospheric air, thus proceeds: "But if, instead of being thus exposed to the influence of the air, a mass of dead vegetable matter be accumulated in such situations as allow of the admission of water, but in which the compactness of the superincumbent stratum of earth, not only excludes the external air, but the disengaged gaseous matters are prevented from escaping, the bituminous fermentation takes place, and bituminous matters are formed in various degrees of maturity and pureness, according to the stage at which the process may have arrived, or the extraneous matters which may have been admitted." Our author, however, admits, that a complete history of all the phenomena which occur during the whole of the operation cannot possibly be expected to be made out, but the proofs of its existence must be obtained by inference, and from analogy on comparing it with the other species of fermentation; and he thus continues: "the substance, then, which I conceive to be entirely dependent on, and actually the product of, this process, is bitumen; a substance which manifests, upon examination, all those properties which might, *a priori*, be expected to be found in a body constituted under the particular circumstances which I have presumed to have directed its formation."

"In the first stage of the vinous fermentation, we perceive that a considerable portion of the more volatile parts of the mixture is dissipated, and that it is only by the careful preservation of the remainder that the accomplishment of this process is effected. In the acetous fermentation this escape of the volatile parts is continued through the whole of the process, and occasions the great difference which exists between the two products. In the first of these species of fermentation, carbon, that principle which always seems to affect that mode of combustion, observable in ignited charcoal, where flame is not present, is, we have remarked, dissipated in very large quantities, by which its dose in the mixture must be considerably diminished; whilst, should hydrogen even be supposed to escape in a similar proportion, still, from the decomposition of the water, sufficient of this principle (which I will call the principle of inflammability) will be yielded, to give the spirituous and very inflammable product which we find to be the result of this process. In the latter of these species of fermentations, in which the dissipation of the volatile matters is carried to the utmost extent which the degree of temperature will admit, the mixture seems to be deprived of almost the whole of its hydrogen; except, perhaps, just so much as is left in combination with the colouring principle, and the water, whilst the oxygen is attracted, nearly in the same proportion, by the carbon from the atmosphere, and from the very

considerable dose of this acidifying principle; and, from some peculiar modification of their union, the product, *vinegar*, results, possessing a high degree of acidity, but not the least degree of inflammability.

"We will now examine the changes which may be expected to result from the decomposition of vegetable matters placed in subterranean situations, and considering these, with the properties which are possessed by the supposed product of the bituminous fermentation, we shall be enabled, especially by recollecting what has been just said of the other species of fermentation, to determine whether it is right to admit of the existence of such a species of fermentation or not.

"Secured on every side by the surrounding earth, the mass of vegetable matter is preserved, at it were, in a well-closed vessel; hardly any escape being permitted to any of its more volatile particles, nor any admission of extraneous matters allowed, except of such as are introduced with the water which may insinuate itself by soaking through the interstices of the earthy particles, composing the several strata which inclose it.

"It is decreed, that a strong disposition to separate, and to unite in another order, shall secure the necessary decomposition of dead organized matter, which, according to the economy of nature, is but to possess a short and transient cohesion. Agreeable to this law, this mass of vegetable matter, now deprived of the energy of vegetable life, must undergo some change; but from the closeness of its preservation, it cannot admit that escape of the gaseous matters on which the commencement of the vinous, acetous, or putrid fermentations depend: another process is therefore instituted. The hydrogen, carbon, and oxygen are disengaged from their former attachments, but being prevented from flying off in a gaseous state, are obliged again to unite, and to enter into new combinations.

"Under these particular circumstances a substance may be expected to be formed, containing a considerable portion of these principles so abundant in vegetable matter. In this respect, there undoubtedly may be discovered a remarkable agreement between the supposed product of this fermentation, and the hypothesis by which its formation is attempted to be explained; since, in all bituminous substances the abundant existence of these three principles has been sufficiently proved by analysis.

"In this, as in every other species of fermentation, a considerable difference may exist, as to the degree of perfection to which the process may proceed, and of course, as to the degree of perfection which the product may possess.

"Thus I expect to shew, that, according to length of time, exclusion from the air, and the existence of other favourable circumstances, will these bituminous substances be found in their several approaches to that state, to which the law of nature seems to have particularly destined them.

"Peat, that combustible and inflammable substance, generally found in considerable masses at a little depth beneath the surface of the earth, possessing chemical properties essentially different from every other substance which has not derived its existence from the same origin, appears to be the first product of this kind of fermentation, and to have been formed in situations not favourable to the rapid completion of this process. The celerity with which this process is accomplished must depend on the closeness with which the gaseous principles are secured; but it should be considered, that such peat-bogs as are, comparatively, but of modern formation, are covered by a coat of vegetable mould, in a humid state, of no considerable degree of thickness, and therefore the escape of the more volatile

principles, and the admission of atmospheric air, are only partially prevented; the process must therefore be carried on with much less effect, than in those cases which will be hereafter mentioned, where vast masses of vegetable matters have been suddenly buried under a considerable thickness of earthy deposition.

"The abundance of hydrogen, carbon, and oxygen, in peat, is demonstrated by its analysis. By the early analysis of Schoockius we learn, that it yields an oil much resembling the oil of amber, with an acid liquor. Mons. Fourcroy relates, that, on exposing peat to the action of heat in a distillatory apparatus, a yellow or reddish foetid water is obtained, an oil of a most disagreeable odour, with carbonate of ammonia, and carbonated hydrogen gas, also smelling most disagreeably; a coal being left, which is frequently pyrophoric, and which yields, after incineration, muriate and sulphate of soda and of pot-ash, mixed with the phosphate and sulphate of lime, and with the oxyds of iron and of manganese.

"The prevalence of hydrogen in this substance is fully displayed by the foregoing analysis, since not only enough exists for the formation of this peculiar oil, but a considerable quantity of this principle is also disengaged in a gaseous form; the agreement, therefore, between this substance, and what might, *a priori*, have been supposed, would be the product of a vegetable matter placed under these particular circumstances, appears to be evident. The original mode of existence which belonged to this substance is sufficiently marked by the great quantities of vegetable substances which are found in it, which have not suffered such an alteration, as to hinder the immediately tracing them to their true origin. That this substance has been subjected to the influence of the two circumstances, which seem essential to this peculiar fermentation, the presence of moisture and subterranean situation, must appear so plain from the state in which the peat mosses are found, that, on this point, not a word need be added. Peat, therefore, I presume, we may regard as a vegetable secondary fossil; having been formed from vegetable matter, changed in its nature and properties by a certain fermentation, which had been carried on in the mineral regions."

The further prosecution of this theory by our author, in order to account for the formation of amber, and jet, &c. are too long for our purpose, but are well worthy the perusal of those who wish to become acquainted fully with this subject.

FERMENTATION, VINOUS, in *Chemistry*. The recent observations of chemists enable us to state with greater precision the changes which sugar undergoes during its conversion into alcohol, than could be done when this article was written for the Cyclopædia.

Sugar is composed, according to Dr. Prout's analysis, of

Hydrogen	-	-	6.66
Carbon	-	-	40.00
Oxygen	-	-	53.33
			<hr/>
			= 100.

which correspond with 1 atom of each element.

Alcohol, according to Dr. Thomson, is a compound of about

Hydrogen	-	-	13.04
Carbon	-	-	52.16
Oxygen	-	-	34.80
			<hr/>
			100.

which correspond with 3 atoms of hydrogen, 2 atoms of carbon, and 1 atom of oxygen; and carbonic acid gas is composed of

Carbon	-	-	-	27.27
Oxygen	-	-	-	72.72

100.

or of 1 atom of carbon and 2 atoms of oxygen.

Hence, if we suppose (for the sake of round numbers) 3 atoms of sugar to be decomposed during the process of fermentation, they will be converted into 1 atom of alcohol and 1 atom of carbonic acid; for

	Hydrogen.	Carbon.	Oxygen.
1 atom alcohol consists of	3 atoms	+ 2 atoms	+ 1 atom
1 atom carbonic acid gas of		1 atom	+ 2 atoms

which make together + 3 + 3

or three atoms of sugar.

Now this determination very nearly coincides with the actual

experiments of Lavoisier, and the more recent determination of Thenard, respecting the proportional quantities of these two products obtained by the fermentation of sugar. Thus 100 parts of sugar (as deduced by Dr. Thomson from Thenard's experiments) were converted into

Alcohol	-	-	57.44
Carbonic acid	-	-	42.56

100.

Whereas the proportions, according to the above calculations, ought to have been

Alcohol	-	-	51.12
Carbonic acid	-	-	48.88

100.

A coincidence as near as could have been expected, considering the very difficult nature of the experiment.

With respect to the *modus operandi* of ferments, we have nothing to add, but that the subject still remains a mystery. See WINE, and YEAST.

File

FILE, an instrument used for reducing, and for giving shape and smoothness to a number of articles made of wood or metal.

It is divided into two varieties from the form of their teeth, namely, files and rasps. The former are cut upon the surface with a sharp-edged chisel. In the latter, the tooth is raised with a triangular punch. The file is adapted for working metals, but the rasp is more fitted for wood, bone and horn. Files again are distinguished by being single or double cut. The single cut file is simply cut once over, and is employed for filing brass, and the softer metals. A second course of teeth is cut to form the double cut file, crossing the first diagonally. This kind is best suited to iron and steel.

Files are also called by different names, from the various degrees of fineness of their teeth, as smooth, second cut, ballard cut, and rough files.

And again, from their shape, they are called flat, half-round, square, three square, round, and some having two round sides.

The steel employed for files requires to be very hard, and in consequence undergoes a longer process in the conversion: it is said to be double converted.

The very heavy files, such as smiths' rubbers, are made of the inferior marks of blistered steel: the more delicate kind, such as watch-makers' files, being made of cast steel. The steel is previously drawn at the tilt, into rods of suitable size.

Forging of Files.—The flat and the square files are made wholly with the hammer, and the plain anvil. Two workmen, one called the maker, and the other striker, are required in the forging of heavy files; the smaller being forged by one person only.

The anvil is provided with a gate, or groove, for the reception of certain bores, or dies, which are used for the purpose of forging the half-round and three-angled files. The half-round bore contains a hollow which is the segment of a sphere, much less than half a circle. That used for the triangular files has a gate or hollow, consisting of two sides, terminating in an angle at the bottom.

In forging the half-round file, the steel is first drawn out, as if intended to make a flat file. It is then laid in the bore, and hammered, till the underside becomes round. The steel for the triangular file is tilted into square rods. The part to form the file is first drawn out with the hammer, as if intended to form a square file. It is then placed in the bore with one of the angles downwards, and by striking upon the opposite angle, two sides of the square are formed into one, and consequently a three-sided figure produced. By successively presenting the different sides to the action of the hammer, the figure is rendered still more complete.

In forming the tangs of most files, it is necessary to make the shoulders perfectly square and sharp. This is performed by cutting into the file a little on each side with a sharp fate or aggron, and afterwards drawing out the part so marked off, to form the tang.

After forging, and previous to being ground and cut, the files require to be annealed. This process is generally performed by piling up a great quantity together, in a furnace for the purpose, and heating them red hot; suffering them afterwards to cool slowly. This method of annealing files, or indeed any other articles, in which great hardness is requisite, is very objectionable, since the surface of steel, when heated red hot in the open air, is so liable to oxydation. Two evils result from this circumstance, besides the loss by waste. First, the scaly oxyd is very hard, and difficult to remove; and secondly the steel, particularly on the surface, is deprived of a portion of its carbon, and thereby rendered less susceptible of hardening.

A superior method of annealing is practised by some file makers, and since hardness in a file is so essential a property, the process ought to be generally adopted.

This method consists in placing the files in an oven or trough, having a close cover, and filling up the interstices with sand. The fire is made to play on every side of this vessel, as gradually, and as uniformly as possible, till the whole mass becomes heated red hot. The fire is then discontinued, and the whole suffered to cool, before the cover is removed from the trough. Another evil may however arise from keeping steel red hot even in a close vessel, for too great a length of time. It assumes a kind of crystallization under which its tenacity is much impaired. Hence, it will be proper not to anneal too many at once, and not to heat them too hot. Steel, annealed in this way, is perfectly free from that scaly surface acquired in the open air; and if each corticle be perfectly surrounded with the sand, and the cover not removed before the steel is cold, the surface will appear of a silvery white colour.

If the steel be suspected to be too kind, from containing too little carbon, powdered charcoal may be employed instead of sand, or sand mixed with charcoal. In this case the files should be stratified alternately with the charcoal, in order that the extra-conversion may be uniform.

The next thing is to prepare the files for cutting, by making the surface, to contain the teeth, as level as possible. This was formerly effected by means of files; and the process is called *stripping*. The same is still practised by the Lancashire file makers, and by others not having convenience for grinding. The greatest quantity of files, however, are ground to prepare them for cutting. The stone employed for the purpose is of the sandstone kind, the texture of which is compact and sharp, but rather rough. They are of as great diameter as can be used with convenience; and about eight inches broad over the face. When used, the surface is kept immersed in water. The grinder sits in such a position as to lean over the stone, while its motion is directly from him. Its surface moves at about the same speed with those used in grinding cutlery. Since the object in grinding files is to make the surface as even and flat as possible, and as this cannot be done so completely upon a small stone, the stones of the file-grinder are laid aside when they are reduced to a certain size, and are employed for

grinding other articles. Though grinding is by far the most expeditious method, it does not give that truth to the surface which can be effected by filing. If the price of the articles would admit, however, it would be well to render the surface more even by the file after grinding. If the surface be not flat, it is obvious, that when the file is used for filing a large surface, those teeth in the hollow parts of the file will not be brought into action. It is from attention to this circumstance, and to the care in annealing and hardening, that the Lancashire file-makers have generally excelled. They are, however, confined chiefly to the small articles, since the larger files would not pay for the process of drying.

Cutting of Files.—If the vast number of teeth contained in a file, and their requisite uniformity are considered, a machine capable of effecting a business so apparently mechanical, may be considered a desideratum.

Though many attempts have been made to accomplish this object by machinery, and several varieties of machines have been constructed for the purpose, no one has yet been sufficiently general in its application, to render the prosecution of such an object very desirable. Among those who have distinguished themselves in this enquiry, Mr. Nicholson, the publisher of the Philosophical Journal, we believe, invented the most likely machine for file cutting, for which he took out a patent. We do not know, however, that either Mr. Nicholson's, or any other machine, is at present used for the purpose. A file, which is of the same breadth and thickness throughout, of any form, may be cut by the machine, because the same magnitude of stroke is required for every tooth; but if the file be comical, it is obvious that a machine, capable of giving all the varieties of strokes required in cutting even one side of a file, would be too complicated to be of any great utility. Again, the chisel employed for cutting a file is frequently liable to slip, or be otherwise out of order. This the workman, in the common way of cutting, can easily feel, and immediately stops to repair it. A very great evil would arise from this source, in cutting with the machine; and this evil would be greater in proportion to the number of chisels which one person had to overlook. It has also been said, but we cannot affirm the fact, that the teeth raised by machinery are not so full and sharp as those formed by hand. Till the above inconveniences can be obviated, in all probability the common method will be continued; the different apparatus and mode of performance of which we will endeavour to describe.

The tools of the file-cutter consist of an anvil placed upon a block of such a height, that the man sits to his work. He has also a piece of lead, or lead alloyed with tin, on which he lays the files when one side is cut. The chisel and hammer are of such size, as the size and cut of the file require. He is also provided with a leather strap, which goes over each end of the file, and passes round his feet, which are introduced into the strap on each side, in the same manner as stirrups are used. The file-cutter, therefore, sits as if he were on horseback, holding his chisel with one hand, his hammer in the other, at the same time he secures the file in its place by the pressure of his feet in the stirrups. A, *fig. 1.* (*Plate XIII. Miscellany.*) is the block; B, the anvil; a b, the file, laid upon the piece of lead; C, C, the stirrups passing over the ends of the file; D, the seat on which the workman sits. *Fig. 2.* is the form of one of the chisels for cutting the files. *Fig. 3.* represents the chisel or punch for raising the tooth of the rasp. *Fig. 4.* the hammer used to strike the head of the chisel. These people have found by experience that there is an advantage in having the head of the hammer hooked inwards. This is easily accounted for,

when we observe that the stroke will be made pretty near the centre of percussion. Great pains ought to be taken in preparing the edge of the chisel. It is, in the first place, hardened and tempered by heating it gradually till it appears of a yellowish brown. It is next ground very true to form the edge, which is afterwards finished upon a Turkey stone, with oil. It is not required to be very sharp, the bottom of the tooth requiring to be rather open, to prevent the file from clogging with the substance to be filed. The edge is also required to be very smooth, in order that it may slip easily upon the surface of the files: this is also facilitated by slightly greasing the surface. From this advantage, the worker, after making one tooth, is enabled, by feeling only, to form, at its proper distance, the succeeding tooth, by sliding the chisel close up against the back of the preceding one. All these motions are performed with astonishing rapidity, first the chisel and then the hammer. We observed a boy, in cutting three-sided files of five inches long, bastard cut, make 225 strokes, which produced as many teeth, in one minute. And the whole file being double-cut, contained 1350 teeth, or six times the above quantity. The second cut file, of the same size, contains 2025 teeth, and the smooth file 2700, consequently, the difference in labour between the bastard-cut and the smooth files is about as two to one. Larger files, from the greater surface, require a much greater stroke to raise the tooth, and consequently fewer strokes will be made in the same time.

In the double-cut files, the first set of teeth, which the workmen call *up-cutting*, are, previous to cutting the second course, filed slightly upon the face, in order to allow the chisel to slide freely.

The single-cut file is more durable than the double-cut, and ought to be preferred for all purposes, excepting for iron and steel.

The same method is employed in cutting the rasp. The workman is however guided completely by his eye, in regulating the distance of the teeth from each other. The rasp ought to be cut in such a manner that no one of the teeth may stand opposite to another. This not only allows the rasp to cut faster, but makes the surface, either of wood or other substance, much smoother.

Hardening of Files.—This is the last and most important part of file-making. Whatever may be the quality of the steel, or however excellent the workmanship, if it is not well hardened, all the labour is lost.

Three things are strictly to be observed in hardening; first, to prepare the file on the surface, so as to prevent it from being oxydated by the atmosphere, when the file is red hot, which effect would not only take off the sharpness of the tooth, but render the whole surface so rough, that the file would, in a little time, become clogged with the substance it had to work. Secondly, the heat ought to be very uniformly red throughout, and the water in which it is quenched fresh and cold, for the purpose of giving it the proper degree of hardness. Lastly, the manner of immersion is of great importance, to prevent the files from warping, which in long thin files is very difficult.

The first object is accomplished by laying a substance upon the surface, which, when it fuses, forms as it were a varnish upon the surface, defending the metal from the action of the oxygen of the air. Formerly, the process consisted in first coating the surface of the file with ale grounds, and then covering it over with pulverized common salt, (muriat of soda.) After this coating became dry, the files are heated red hot, and hardened; after this, the surface is lightly brushed over with the dust of coals, when it appears white and metallic, as if it had not been heated. This process has

lately been improved, at least so far as relates to the economy of the salt, which, from the quantity used, and the increase of duty, had become a serious object. Those who use the improved method are now consuming about one-fourth the quantity of salt used in the old method. The process consists in dissolving the salt in water to saturation, which is about three pounds to the gallon, and stiffening it with ale grounds, or with the cheapest kind of flour, such as that of beans, to about the consistence of thick cream. The files only require to be dipped into this substance, and immediately heated and hardened. The grounds, or the flour are of no other use, than to give the mass consistence, and by that means, allowing a larger quantity of salt to be laid upon the surface. In this method, the salt forms immediately a firm coating. As soon as the water is evaporated, the whole of it becomes fused upon the file. In the old method the dry salt was so loosely attached to the file, that the greatest part of it was rubbed off into the fire, and was sublimed up the chimney, without producing any effect.

The carbonaceous matter of the ale-grounds is supposed to have some effect, in giving hardness to the file, by combining with the steel, and rendering it more highly carbonated. It will be found, however, upon experiment, that vegetable carbon does not combine with iron, with sufficient facility, to produce any effect, in the short space of time a file is heating, for the purpose of hardening. Some file makers are in the habit of using the coal of burnt leather, which doubtless produces some effect; but the carbon is generally so ill prepared for the purpose, and the time of its operation so short, as to render the effect very little. Animal carbon, when properly prepared and mixed, with the above hardening composition, is capable of giving hardness to the surface even of an iron file.

The carbonaceous matter may be readily obtained from any of the soft parts of animals, or from blood. For this purpose, however, the refuse of shoe-makers and curriers, is the most convenient. After the volatile parts have been distilled over, from an iron still, a bright shining coal is left behind, which, when reduced to powder, is fit to mix with the salt. Let about equal parts, by bulk, of this powder, and muriat of soda, be mixed together, and brought to the consistence of cream, by the addition of water. Or mix the powdered carbon with a saturated solution of the salt, till it become of the above consistence. Files which are intended to be very hard, should be covered with this composition, previous to hardening. All files intended to file iron or steel, particularly saw files, should be hardened with this composition in preference to that with the flour or grounds. Indeed, we are of opinion, that the carbonaceous powder might be used, altogether, in point of economy, since the ammonia or hartshorn, obtained by distillation, would be of such value as to render the coal of no expence.

By means of this method the files made of iron, which in itself is insusceptible of hardening, acquires a superficial hardness, sufficient for any file whatever. Such files may at the same time be bent into any form, and, in consequence, are particularly useful for sculptors and die sinkers.

The next point to be considered is the best method of heating the file for hardening. For this purpose a fire, similar to the common smiths' fire, is generally employed. The file is held in a pair of tongs, by the tang, and introduced into the fire, consisting of very small coals; pushing it more or less into the fire for the purpose of heating it regularly. It must frequently be withdrawn for the purpose of observing, that it is not too hot in any part. When it is uniformly heated, from the tang to the point, of a cherry red colour, it is fit to quench in the water. At present an oven, formed of fire bricks, is used for the larger files, into which the blast of the bellows is directed, being open at one end, for the purpose of introducing the files and the fuel. Near to the top of the oven are placed two cross bars, on which a few files are placed, to be partially heating. In the hardening of heavy files, this contrivance affords a considerable saving, in point of time, in addition to which they are more uniformly and thoroughly heated.

After the file is properly heated for the purpose of hardening, in order to produce the greatest possible hardness, it should be cooled as soon as possible. The most common method of effecting this is by quenching it in the coldest water. Some file makers have been in the habit of putting different substances in their water, with a view to increase its hardening property. The addition of the sulphuric acid to the water was long held a great secret in the hardening of saw files. After all, however, it will be found, that clear spring water, free from animal and vegetable matter, and as cold as possible, is the best calculated for hardening files of every description.

In quenching the files in water some caution must be observed. All files, except the half round, should be immersed, perpendicularly, as slowly as possible, so that the upper part shall not cool. This management prevents the file from warping. The half round file must be quenched in the same steady manner, but at the same time it is kept perpendicular to the surface of the water, it must be moved a little horizontally, in the direction of the round side, otherwise it will become crooked backwards.

When the files are hardened, they are brushed over with water and powdered coals, when the surface becomes perfectly clean and metallic. They ought, also, to be washed well, in two or three clean waters, for the purpose of carrying off all the salt, which, if remaining, will be liable to rust the file. In addition to this, they should be dipped into lime water, and rapidly dried before the fire, after being oiled, with olive oil, containing a little oil of turpentine, while still warm, and they are deemed finished.

Filing

FILING, in *Mechanics*, is the operation of using a file in cutting away and reducing various substances into any required form. The file is chiefly confined to the working of metal, though it is occasionally applied to wood, ivory, bone, &c. The art of filing is an essential to every workman in metal, and it requires great practice and skill to perform it well: the principal difficulty consists in filing a truly plane and even surface to any piece of metal. To do this, the work must be held firmly in a vice, so that the surface to be filed be truly horizontal; the workman then files it over with a file, adapted in its cut, or size of its teeth, to the magnitude of his work: in doing this, if it is large, he takes one end of the file in each hand, holding it firmly, as he moves it backwards and forwards, in a horizontal plane, taking care not to lean heavier upon one end of the file than the other. The file only cuts in going forwards; he must therefore press harder upon it, that it may take hold of the metal: in drawing it back it is unnecessary to lean on the file, because it is not then adapted to act; it is usual, in filing a piece of flat work, to begin at one side, and every time the file is drawn back, to move it sideways at the same time about the breadth of the file: the next stroke proceeds straight forwards, as before, but in a fresh place, unless some sudden eminence is to be reduced; then two or more strokes should be made in one place, or the pressure on the file increased till all is brought to a flat or even surface. When the whole of the work has been done over in one direction, it is then filed in the same manner at right angles thereto, and afterwards diagonally, till it is finished, trying it occasionally by a straight edged ruler. Some work-

men, by long practice and experience, are able to make the work flat by filing in one direction only, and without any trial; so that if two surfaces of metal thus filed are placed one upon the other, they will adhere together for an instant if the upper one be suddenly lifted up. The height of the vice, in which the work is held, is a matter of some importance in filing; if the work is large, it should be about forty inches above the floor on which the workman stands; for small work it may be higher, because the workman does not need to bear so heavily on the work. In filing articles which are to be fitted together, the workman makes use of bevels, gauges, rulers, compasses, &c. to mark out and try the work. Round pins, &c. are held in a hand-vice, and supported on a piece of wood while they are filed, and the workman turns them round while he files, in order that they may be truly round and have no angles.

The file-makers in Lancashire, for cutting the teeth of their small files, sometimes make use of a knife, *fig. 5. Plate XIII. Miscellany*, which has a beveled edge; the workman uses it in the same manner as the chisel, except that no hammer is employed. The finest files used by watch-makers have sometimes as many as 350 teeth *per* inch, which are frequently cut by the knife; other watch-makers' files are cut in the manner above described, by the chisel, *fig. 6*, which is struck on the head by a small hammer. The smallest chisels used are not a vast deal larger than the figure, and the hammer, *fig. 7*, is the full size, though the handle in reality is somewhat longer; some of very fine watchmakers' files are not larger than needles, and are called needle-files.

Fire-engine

FIRE-engine, is a machine for extinguishing accidental fires by means of a stream or jet of water. The common squirting fire-engine consists of a lifting pump placed in a circular or cylindric vessel of water, and wrought by two levers that act always together. During the stroke, the quantity of water raised by the piston of the pump spouts with force through a pipe joined to the pump-barrel, and made capable of any degree of elevation by means of a yielding leather pipe, or by a ball and socket turning every way, screwed on the top of the pump. The vessel containing the water is covered with a strainer, which prevents the dirt and filth poured into it with the water from choking the pump-work. Between the strokes of this engine the stream is discontinued for want of an air-vessel. However, in some cases, engines of this construction have their use, because the stream, though interrupted, is much smarter than when the engine is made to throw water in a continued stream. The best engine of this latter kind is that of Mr. Newsham, formerly an engine-maker in London. A perspective view of the whole engine, ready for working, is represented in *Plate III. Hydraulics, &c. fig. 4.*

This engine consists of a cistern A B, about three times as long as it is broad, made of thick oaken planks, the joints of which are lined with sheet-copper, and easily moveable by means of a pole and cross bar C in the fore part of the engine, which is so contrived as to slide back under the cover of the cistern, and on four solid wheels, two of which are seen at D and E. The hind axle-tree, to which the wheel E and its opposite are fixed, are fastened across under the bottom of the cistern; but the fore axle-tree, bearing the wheel D, &c. is put on a strong pin or bolt, strongly fastened in a horizontal situation in the middle of the front of the bottom of the cistern, by which contrivance the two fore wheels and the axle tree have a circular motion round the bolt, so that the engine may stand as firm on rough or sloping ground as if it was level. Upon the ground next to the hind part of the engine may be seen a leathern pipe F, one end of which may be screwed on and off upon occasion to a brass cock at the lower end of the cistern: the other end is immersed in the water, supplied by a pond, fire-plug, &c. and the pipe becomes a sucking pipe for fur-

wishing the pumps of the engine by its working, without pouring water into the cistern. To the hind part of the cistern is fastened a wooden trough G, with a copper grate for keeping out stones, sand, and dirt, through which the cistern is supplied with water when the sucking pipe cannot be used. The fore part of the cistern is also separated from the rest of its cavity by another copper grate, through which water may be poured into the cistern. Those that work the pumps of this engine move the handles visible at the long sides, up and down, and are assisted by others who stand on two suspended treddles, throwing their weight alternately on each of them, and keeping themselves steady by taking hold of two round horizontal rails, H, I, framed into four vertical stands, which reach to the bottom of the cistern, and are well secured to its sides. Over the hind trough there is an iron handle or key K, serving to open or shut a cock placed under it on the bottom of the cistern, the use of which we shall explain in the sequel of this article. L is an inverted pyramidal box or case which preserves the pumps and air vessels from damage, and also supports a wooden frame M, on which stands a man, who, by raising or depressing, and turning about the spout N, directs the stream of water as occasion requires. This spout is made of two pieces of brass pipe, each of which has an elbow; the lower is screwed over the upper end T (see *fig. 5.*) of the pipe that goes through the air-vessel, and the upper part screws on to the lower by a screw of several threads, so truly turned as to be water-tight in every situation. The conic form of the spouting-pipe serves for wire-drawing the water in its passage through it, which occasions a friction that produces such a velocity of the jet as to render it capable of breaking windows, &c. whilst the valves and leathern pipes of the engines have sufficient water-way to supply the jet in its greatest velocity. Leather pipes of considerable length may be screwed at one end of the nosel of the engine, and furnished at the other end with a wooden or brass pipe for guiding the water into the inner apartments of houses, &c. Between the pyramidal box L, and the fore-end of the engine, there is a strong iron bar O, lying in an horizontal position over the middle of the cistern, and playing in brasses supported by two wooden stands; one of which, P, is placed between the two fore-stands of the upper rails, and the other is hid in the inclosure over the hind part. Upon proper squares of this bar are fitted, one near each end, two strong cross bars, which take hold of the long wooden cylindrical handles, by means of which the engine is worked; and the treddles by which they are assisted are suspended at each end by chains in the form of a watch chain, and receive their motion jointly with the handles that are on the same side, by means of two circular sectors of iron fastened together, and fixed upon proper squares of the middle horizontal bar; the two fore ones may be seen at Q; the two hind ones represented on a large scale in *fig. 6.* differ from the former only in thickness; for the fore sectors are made to carry only one chain each, fastened by one end to their upper part, and by the lower end to the treddles; whereas the sole of the two hind sectors is wide enough to carry two chains each; one set fastened like those of the fore ones for the motion of the treddles; and the other two chains are fastened by their lower ends to the lower part of these sectors, and by their upper ends to the top of the piston bars, in order to give them motion. See *fig. 6.* in which the hind sectors and their apparatus are represented as they would appear to a person standing between the two fore-wheels, and looking at the hind part of the engine. The square over the letter A is the section of the middle bar, on which, right over

the two barrels, are placed the two sectors BCA and DEA, forged together. EGHK and *fg h k* are the two piston rods; and the openings between the letters G, H, and *g, h*, are the spaces through which the hind parts of the two treddles pass. L and M represent two strong studs rivetted on the other side of the bars on which they are placed; and to each of these is fastened a chain like a watch-chain, fixed by their upper ends to the upper extremities D and B of the iron sectors, by which they are drawn up and down alternately. These sectors give also an alternate motion up and down to the piston-rods, by means of two other chains left white in the figure, in order to distinguish them from the others: these are fastened by their lower ends to the lower extremities of the sectors E and C, and their upper ends terminating in a male screw, are made tight to the piston-rods at I and *j*, by two nuts. The shape of the piston-rods, and the size and situation of the chains that give them motion, are so contrived, that the vertical axis of the pistons is exactly in the middle of the breadth of the perpendicular part of the chains, and the upper part of the piston-rod taken together. PQ represents one of the two cross bars through the ends of which pass the long handles to which the men apply their hands when they work the engine; these cross bars are fitted on the middle bar at some distance from the sectors.

The other parts of this useful engine may be understood by the help of *fig. 5.* which represents a vertical section taken through the middle line of the hind part of the engine, as also the section of the air-vessel, and that of one of the barrels, and likewise the profiles of the hind sectors, and of several other parts. A B is the section of the bottom of the cistern, and C that of the hindmost axle-tree. D E is the vertical section of a strong piece of cast brass or hard metal, so worked as to have a hollow in it, represented by the white part, and fixed to the bottom of the cistern: this reaches from the opening D through the cock W, and afterwards divides itself into two branches, so as to open under the two barrels; one of these branches is exhibited in the figure, and the other is exactly behind this. Through this channel, which may be called the sucking-piece, water is conveyed to the pumps by the pressure of the atmosphere, either from the cistern itself, or from any place at a distance, by means of a leathern pipe F, *fig. 7.* which screws on to the sucking-piece at D, *fig. 5.* under the hind trough Z, the grate of which is represented by the horizontal strokes. F G represents the vertical section of another piece of cast brass or hard metal that may be called the communication-piece, having two hollows for conveying the water from under the two pistons to the two openings of the flanch of the air-vessel; one of these hollows appears in the figure; the other lies exactly behind this, though not in a parallel direction. Between the section of the sucking-piece D E, and that of the communication-piece F G, may be observed the section of one of the plates of leather, which makes all tight, and forms one of the two sucking valves, of which there is another just behind this under the other barrel. R S T is the section of the copper air-vessel, and T V that of the conduit-pipe; this vessel is screwed on to the hind part of the communication-piece, and at top is fastened by a collar of iron to a cross piece of timber. Between the flanch of the air-vessel and the communication-piece may be observed the section of one of the plates of leather, making all tight, and screwing one of the two forcing valves, of which there is another just behind this, exactly over the other opening of the communication from the air-vessel. These valves are loaded

with a lump of cast iron or lead, having a tail or teat let through the flap of the valve and cross-pinned under it; and it is to be observed, that though both the valves are represented open in the figure, they are never both open at the same time; for when the engine is not at work they are closed down by the weights on their upper surfaces; and when the engine works, two are shut, and the other two are open alternately by the motion of the pistons and the action of the atmosphere, together with the reaction of the air contained in the air-vessel. H I is the section of one of the barrels of the two pumps, which are both sucking and forcing, as is evident from the position of the valves and the structure of the pistons, each of which is composed of two iron plates, of two wooden trenchers, and of two flat pieces of leather turning one up and the other down. L K represents one of the piston-rods edge-wise, behind which is one of the chains, the top screw of which, K, can only be seen. M is the end of the middle bar, and N a section of the hindmost of the two middle stands which support the middle bar. O represents the end of the profile of one of the treddles, passing through the rectangular holes of the piston-rods, as in *fig. 8*. The weight on these treddles brings them and the piston-rods down alternately, and they are raised up again by help of the other set of chains, one of which may be seen edge-wise in this figure, placed on the sole of one of the sectors, &c. See *fig. 6*.

P Q is part of the cross bars which carry the handles seen edge-wise, and X Y represents an iron handle, by the help of which the cock W may be placed in the several situations requisite for the use of the engine. The mechanism of the cock W may be understood by *figs. 9, 10, and 11*, which represent the horizontal section of it in three different situations. It has three holes that are left white in these figures. In *fig. 9*, the position of the cock is represented when the handle X Y or K is in a direction parallel to D E, or to the middle bar, as in *fig. 5*, and *fig. 4*. In this position, the water supplied by the sucking-piece enters at D, and proceeds directly through the cock W to the valve under the two pistons; and there is now no communication from the barrels with the cavity of the cistern. In *fig. 10*, we have the position of the cock when the handle X Y is turned one quarter of a revolution towards the eye from the last mentioned situation, in which case there is no communication from the barrels with the outer extremity of the sucking-piece, but the water poured into the fore and hind trough, and passing from thence into the cavity of the cistern, enters the cock side-wise at W, and, turning at right angles through the cock towards E, proceeds to the barrels of the pumps. *Fig. 11* represents the cock W when the handle is placed diametrically opposite to its last situation, in which case there is no communication from the under-side of the barrels with the cavity of the cistern or the outward end of the sucking-piece; but this situation affords a communication from the cavity of the cistern with the outside of the engine, and the water left in the cavity of the cistern may by this means be employed when the engine has done working. These engines are made of five or six different sizes. See Desaguliers's *Course of Exper. Philos.* vol. ii. p. 505—518.

The principles on which this engine acts, so as to produce a continued stream, are obvious; the water, being driven into the air-vessel, as in the operation of common sucking and forcing pumps, will compress the air contained in it, and proportionably increase its spring, since the force of the air's spring will always be inversely as the space

which it possesses; therefore, when the air-vessel is half filled with water, the spring of the included air, which in its original state counterbalanced the pressure of the atmosphere, being now compressed into half the space, will be equal to twice the pressure of the atmosphere; and by its action on the subjacent water will cause it to rise through the conduit-pipe, and to play a jet of 32 or 33 feet high, abating the effect of friction. When the air-vessel is two-thirds full of water, the space which the air occupies is only one-third of its first space; therefore its spring being three times as great as that of the common air, will project the water with twice the force of the atmosphere, or to the height of 64 or 66 feet. In the same manner, when the air-vessel is three-fourths full of water, the air will be compressed into one-fourth of its original space, and cause the water to ascend in air with the force of three atmospheres, or to the height of 96 or 99 feet, &c. as in the following table:

Height of the water.	Height of the compressed air.	Proportion of the air's spring.	Height to which the water will rise.
1	1	2	33 feet
2	2	3	66
3	3	4	99
4	4	5	132
5	5	6	165
6	6	7	198
7	7	8	231
8	8	9	264
9	9	10	297
10	10		

See Martin's *Philos. Brit.* vol. ii. p. 69, &c.

The fire engine, by Rowntree, is a double-force pump, of a peculiar construction, similar in its action to the *beer-engine*, but as it is on a much larger scale, its constructions are of course varied. In this engine, *figs. 1. and 2. Plate IV. Hydraulics*, are two elevations at right angles to each other, of the external part of the engine mounted on four wheels. *Figs. 3. and 4.* are two sections perpendicular to each other, of the body of the engine or pump; *figs. 5. and 6.* are parts of the engine. The same letters are used as far as they apply in all the figures, A, A, A, A; *fig. 3. and 4.* is a cast-iron cylinder truly bored, ten inches diameter and fifteen long, and having a flanch at each end whereon to screw two covers, with stuffing boxes, *a, a*, in their centres, through which the spindle, B, B, of the engine passes, and being tight packed with hemp round the collar, makes a tight joint; the piston, D, is affixed to the spindle within the cylinder, and fits it tight all round by means of leathers; at E, *fig. 4.* a partition, called a saddle, is fixed in the cylinder, and fits against the back of the spindle tight by a leather.

We have now a cylinder divided by the saddle, E, and piston, into two parts, whose capacity can be increased and diminished by moving the piston, with proper passages and valves to bring and convey away the water: this will form a pump. These passages are cast in one piece with the cylinder: one, *d*, for bringing the water is square, and extends about $\frac{1}{3}$ round the cylinder; it connects at bottom with a pipe, *e*; at its two upper ends it opens into two large chambers, *f, g*, extending near the whole length of the cylinder, and closed by covers, *h, h*, screwed on; *i, k*, are square openings (shewn by dotted squares in *fig. 3.*) in the cylinder communicating with the chambers: *f, g, l, m*, are two valves, closing their ends of the curved passage, *d*, and preventing any

water returning down the passage, *d*; *n, o*, are two passages from the top of the cylinder to convey away the water; they come out in the top of the cylinder, which, together with the top of the chambers, *f, g*, form a large flat surface, and are covered by two valves, *p, q*, to retain the water which has passed through them. A chamber, *K*, is screwed over these valves, and has the air-vessel, *k*, figs. 1. and 2. screwed into its top; from each side of this chamber a pipe, *wv*, proceeds, to which a hose is screwed, as shewn in fig. 1. Levers, *x, x*, are fixed to the spindle at each end, as shewn in fig. 1, and carry the handles, *H, H*, by which men work the engine. When the piston moves, as shewn by the arrow in fig. 4. it produces a vacuum in chamber, *f*, and that part of the cylinder contiguous to it; the water in the pipe, *e*, then opens the valve, *m*, and fills the cylinder. The same motion forces the water contained in the other part of the cylinder through the valve, *q*, into chamber, *K*, and thence to the hose through the pipe, *w*; the piston being turned the other way, reverses the operation with respect to the valves, though it continues the same in itself. The pipe, *e*, is screwed by a flanch to an upright pipe, *P*, fig. 5. connected with another square iron pipe, fastened along the bottom of the chest of the engine; a curved brass tube, *G*, comes from this pipe through the end of the chest, and is cut into a screw to fit on the suction hose when it can be used; at other times a close cap is screwed on, and another brass cap at *H*, within the chest, is screwed upwards on its socket, to open several small holes made in it, and allow the water to enter into the pipe; in this case the engine chest must be kept full of water by buckets. The valves are made of brass, and turn upon hinges. The principal advantage of the engine is the facility with which it is cleaned from any sand, gravel, or other obstructions, which a fire-engine will always gather when at work.

The chambers, *f, g*, being so large, allow sufficient room to lodge a greater quantity of dirt than is likely to be accumulated in the use of the engine at any one fire, and if any of it accidentally falls into the cylinder, it is gently lifted out again into the chambers by the piston, without being any obstruction to its motion: to clear the engine from the dirt, two circular plates, *r, r*, five inches diameter, are unscrewed from the lids, *b, b*, of the chambers, *f, g*, and when cleaned are screwed on again: these screw covers fit perfectly tight without leather, and can be taken out, the engine cleared, and enclosed again in a very short time, even when the engine is in use, if found necessary.

The two upper valves, *p, q*, and chamber, *K*, can also be cleared with equal ease, by screwing out the air-vessel, *k k*, fig. 1. which opens an aperture of five inches, and fits airtight, without leather, when closed. The valves may be repaired through the same openings. The use of the air-vessel, *k k*, figs. 1. and 2. is to equalize the jet from the engine during the short intermittance of motion at the return of the piston stroke; this it does by the elasticity of the compressed air within it, which forces the water out continually, though not supplied quite regularly from the engine.

The engine from which our drawing was taken was made for the Sun Fire Insurance Company, in London, and from some experiments made by their agent, Mr. Samuel Hubert, appears to answer every purpose.

FIRE-engine is also a name frequently given to a machine for raising water by steam, more properly called *steam-gine*, which see.

FIRE-escape, a machine for escaping from windows when houses are on fire. Various machines of this kind have been invented by different persons; the following seems to be well adapted to the purpose for which it was designed. It was ori-

ginally invented by the late John Daniel Maseres, esq.; and B. M. Forster, esq. has communicated to the public a description of it, with some improvements by himself, in the Philosophical Magazine. The principal parts of this machine, which is called the "sliding fire-escape," are as follows: 1. The suspension iron *A*, (*Plate XII. Miscellany*, fig. 12.), which is formed like a ram-head commonly used for sliding goods from warehouses, with this difference, the bottom hooks are turned up close to the upright part, to form two close rings or eyes; the length of this iron is about four inches and a half, thickness of the iron out of which it is hammered is about half an inch.

2. The rope *B*. This is made of flax, and platted in a peculiar manner, for which there was a patent taken out. It is sold by Armstrong, St. John's-square, Clerkenwell, and measures about three-eighths of an inch in diameter. The rope must be in length somewhat more than twice the height of the window from the ground.

3. The regulator *C*. This is an oblong piece of beech-wood, six inches and a half in length, three inches and a quarter broad, and about seven-eighths of an inch thick; in this there are four holes pierced for the rope to pass through; one of these is open at the side; there is also a notch at the top of this piece of wood, and an oblong hole about seven-eighths of an inch from the bottom.

4. The upper belt *D* is a stout leathern strap, about four feet three inches long, and one and a half broad, with a buckle to it.

5. The lower belt *E* is a strap of the same sort as the other; but the end, after being put through the buckle, is sewed down; this is for the purpose of security, in case the tongue of the buckle should by accident break.

6. The union strap *F*, so called from its connecting the regulator to the other parts of the machine. This is leathern, and is about a foot and a half long, and an inch and a quarter broad; it has, like the others, a buckle to it. It is stained black, which distinguishes it from the other leathern straps.

The method of putting together all these parts of the machine is, first to pass one end of the rope through the holes in the regulator, then through the two lower rings of the suspension iron; the upper belt is then to be passed through a doubling of the union strap; after which the rope is to be tied to that belt, and the knot secured by a string from slipping (which string is to pass through two small holes in the leather); and at about a foot below the rope is to be tied to the lower belt in like manner. Next, the union strap is to be put through the oblong hole in the regulator, and buckled; by which the upper belt and the regulator will be connected. The other end of the rope may be kept wound on a wooden roller, to prevent it from getting entangled.

Persons who purchase these machines should have a very strong iron hook, with a spring-catch, fixed to some secure part of the window-frame, or elsewhere; on this hook the suspension iron is to be hung by the upper ring, when any one wishes to descend from the window. The next operation is to step into the lower belt with both feet, and draw it up sufficiently high, so as to form a kind of swing to fit

the part of the strap which is through the buckle is to be laid hold of with the left hand; and the buckle, with the right hand, is to be slipped to its proper place, according to the size of the person; the tongue is then to be put into one of the holes, as in buckling common straps. After this is done, the upper belt is to be somewhat loosely buckled round the chest, and then the rope which is on the roller is to be thrown out of the window on the ground.

FIRE-ENGINE

Now all being ready for descending, the person is to get out of the window, grasping tight with one or with both hands, the rope at some convenient part, taking especial care not to meddle with the suspension iron until quite out of the window; after which the rope below the regulator is to be laid hold of with the right hand, and to be let to run through the holes as fast as there may be occasion; for which purpose, if necessary, it may be easily slipped out of the open hole; it will then have the check of only three holes: if the motion is wanted to be retarded, the rope is to be put into the notch at the upper part of the regulator.

When one person has descended, and there is a necessity for a second immediately to follow, the union strap is to be unbuckled; when the regulator will be separated from the upper belt: the belts may then be very easily drawn up, having the friction of the suspension iron only, and the person above is to put on the belts as the other did, and is to be let down gradually, partly by the one below, and partly by managing the rope as the first did: in this case great care must be taken, as the check occasioned by the regulator is gone.

Observations and Cautions.

It is not easy to lay down exact rules for what number of holes the rope must pass through, as this must vary according to the weight of the person, and other circumstances. It would be well, before the person gets out of the window to examine, first, (absolutely necessary,) whether the suspension iron is on the hook; then, that the three buckles are fast, the two knots tied, and that the rope is in the hole of the regulator which has the opening. Great care must be taken that there is not any impediment to the free running of the rope; for which the wall of the house must be examined, and any nails or hooks which may chance to be there removed; also iron scrapers, and every thing wherein the rope may be likely to hitch.

Mr. B. M. Foster has, in some respects, simplified Mr. Maseres's machine, particularly in substituting the ram-head suspension iron in the place of a more complicated, and, in his opinion, less secure piece of mechanism. (See *fig. 13.*) It consists of a solid metal (in the latter improved ones) grooved cylinder, round which the rope coiled two or three times, by which a considerable degree of friction was produced, and the rapid descent prevented, which would otherwise happen. The metal cylinder is supported on an iron frame, and suspended by a ring, which ring is moveable in the socket. A is the moveable ring in the upper part of the frame; B is the frame, enclosing a grooved cylinder; and C is a metal bar to hold the cheeks together.

FIRE, *Everlasting*, in *Pagan Theology*, is a kind of reputed sacred fire worshipped by the Gavers or Gabres in Persia. Dr. Mounsey, formerly physician to the czarina's army, has given the following account of it: this perpetual fire rises out of the ground in the peninsula of Abcheron, about twenty miles from Baku, and three miles from the Caspian shore. The ground is rocky, over which is a shallow covering of earth. If a little of the surface be scraped off, and fire be applied to the hollow, it catches flame immediately, and burns without intermission, and almost without consumption; nor is it ever extinguished unless some cold earth be thrown over it, by which it is easily put out. There is a spot of ground, about two English miles in extent, which has this property, where the earth continually burns; but the most remarkable part of it is a hole about four feet deep, and fourteen in diameter. This fire is worshipped, and is said to have burnt many thousand years. The

cracks in the walls of the caravansera, inhabited by the religious, are covered with flame, if a candle be held to them; and when there is occasion for a small light, no more is necessary than to stick one end of a piece of reed in the ground, and apply a lighted candle to the other; a flame will kindle at the top of the reed, and burn till it is extinguished by covering it. They burn stones into lime, by filling a hole in the ground with a heap of them, and bringing a lighted candle to the hole, upon which the fire kindles, and in about three days burns the stones sufficiently. The flame yielded by this fire, has neither smoke nor smell. This sacred and adored phenomenon is nothing more than an inflammable vapour, which issues in great quantity out of the ground in this place, and is supplied by the naphtha with which the adjacent country abounds. Phil. Trans. vol. xlv. for 1748, p. 296.

FIRE, *Extinguishing of*. The world has long been of opinion, that a more ready way than that in general use, might be found for extinguishing fires in buildings, and it has generally been attempted upon the doctrine of explosion. Zachary Grey was the first person who put this plan into execution with any tolerable degree of success. He contrived certain engines, easily manageable, which he proved before some persons of the first rank to be of sufficient efficacy, and offered to discover the secret by which they were contrived, for a large premium given either from the crown, or raised by a subscription of private persons. But this scheme meeting with no better success than things of this nature usually do, he died without making this discovery. Two years after this the people who had his papers found the method; and it was shewn before the king of Poland and a great concourse of nobility at Dresden, and the secret purchased at a very considerable price. After this the same person carried the invention to Paris and many other places, and practised it every where with success. The secret was this: a wooden vessel was provided holding a very considerable quantity of water; in the centre of this there was fixed a case made of iron plates, and filled with gun-powder; from this vessel, to the head of the larger vessel containing the water, there proceeded a tube or pipe, which might convey the fire very readily through the water to the gun-powder contained in the inner vessel. This tube was filled with a preparation easily taking fire, and quickly burning away; and the manner of using the engine was to convey it into the room or building where the fire was, with the powder in the tube lighted. The consequence of this was, that the powder in the inner case soon took fire, and, with a great explosion, burst the vessel to pieces, and dispersed the water every way: thus was the fire put out in an instant, though the room was flaming before in all parts at once. The advantage of this invention was, that at small expence, and with the help of a few people, a fire in its beginning might be extinguished; but the thing was not so general as it was at first expected that it would prove; for though of certain efficacy in a chamber or close building where a fire had but newly begun; yet when the mischief had increased so far, that the house was fallen in, or the top open, the machine had no effect. This was the contrivance first discovered by Grey, and from which our chemist Godfrey took the hint of the machine, which he called the water-bomb, and would fain have brought into use in England. Act. Eruditor. ann. 1721. p. 183. (See *WATER-Bomb*.) Dr. Hales proposed to check the progress of fire by covering the floors of the adjoining houses with earth. The proposal is founded on an experiment which he made with a fir board, half an inch thick, part of which he covered with an inch depth of

damp garden mould, and then lighted a fire on the surface of the mould; though the fire was kept up by blowing, it was two hours before the board was burnt through, and the earth prevented it from flaming. The thicker the earth is laid on the floors, the better; however, Dr. Hales apprehends, that the depth of an inch will generally be sufficient; and he recommends to lay a deeper covering on the stairs, because the fire commonly ascends by them with the greatest velocity. *Phil. Transf. vol. xlv. for 1748, p. 277.*

Mr. Hartley made several trials in the years 1775 and 1776, in order to evince the efficacy of a method which he had invented for restraining the spread of fire in buildings. For this purpose thin iron plates are well nailed to the tops of the joists, &c. the edges of the sides and ends being lapped over, folded together, and hammered close. Partitions, stairs, and floors, may be defended in the same manner; and plates applied to one side have been found sufficient. The plates are so thin as not to prevent the floor from being nailed in the joists in the same manner as if this preventative were not used; they are kept from rust by being painted or varnished with oil and turpentine. The expence of this addition, when extended through a whole building, is estimated at about five *per cent.* Mr. Hartley had a patent for this invention, and parliament voted a sum of money towards defraying the expence of his numerous experiments. (14 Geo. III. cap. 85.) The same preservative may also be applied to ships, furniture, &c.

Lord Mahon (now earl Stanhope) has also discovered and published a very simple and effectual method of securing every kind of building against all danger of fire. This method he has divided into three parts, *viz.* under-flooring, extra-lathing, and inter-securing. The method of under-flooring is either single or double: in single under-flooring, a common strong lath of oak or fir, about one-fourth of an inch thick, should be nailed against each side of every joist, and of every main timber, supporting the floor which is to be secured. Other similar laths are then to be nailed along the whole length of the joists, with their ends butting against each other. The top of each of these laths or fillets ought to be at $1\frac{1}{2}$ inch below the top of the joists or timbers against which they are nailed; and they will thus form a sort of small ledge on each side of all the joists. These fillets are to be well bedded in a rough plaster hereafter mentioned, when they are nailed on, so that there may be no interval between them and the joists; and the same plaster ought to be spread with a trowel upon the tops of all the fillets, and along the sides of that part of the joists which is between the top of the fillets and the upper edge of the joists. In order to fill up the intervals between the joists that support the floor, short pieces of common laths, whose length is equal to the width of these intervals, should be laid in the contrary direction to the joists, and close together in a row, so as to touch one another: their ends must rest upon the fillets, and they ought to be well bedded in the rough plaster, but are not to be fastened with nails. They must then be covered with one thick coat of the rough plaster, which is to be spread over them to the level of the tops of the joists; and in a day or two this plaster should be trowelled over, close to the sides of

the joists, without covering the tops of the joists with it.

In the method of double flooring, the fillets and short pieces of laths are applied in the manner already described; but the coat of rough plaster ought to be little more than half as thick as that in the former method. Whilst this rough plaster is laid on, some more of the short pieces of laths above-mentioned must be laid in the intervals between the joists upon the first coat, and be dipped deep in it. They should be laid as close as possible to each other, and in the same direction with the first layer of short laths. Over this second layer of short laths there must be spread another coat of rough plaster, which should be trowelled level with the tops of the joists, without rising above them. The rough plaster may be made of coarse lime and hair; or, instead of hair, hay chopped to about three inches in length may be substituted with advantage. One measure of common rough sand, two measures of slacked lime, and three measures of chopped hay, will form in general a very good proportion, when sufficiently beat up together in the manner of common mortar. The hay should be put in after the two other ingredients are well beat up together with water. This plaster should be made stiff; and when the flooring boards are required to be laid down very soon, a fourth or fifth part of quick-lime in powder, formed by dropping a small quantity of water on the lime-stone a little while before it is used, and well mixed with this rough plaster, will cause it to dry very fast. If any cracks appear in the rough plaster-work, near the joists, when it is thoroughly dry, they ought to be closed by washing them over with a brush wet with mortar wash: this wash may be prepared by putting two measures of quick lime, and one of common sand, in a pail, and stirring the mixture with water till the water becomes of the consistence of a thin jelly.

Before the flooring boards are laid, a small quantity of very dry common sand should be strewed over the plaster-work, and struck smooth with an hollow rule, moved in the direction of the joists, so that it may lie rounding between each pair of joists. The plaster-work and sand should be perfectly dry before the boards are laid, for fear of the dry rot. The method of under-flooring may be successfully applied to a wooden stair-case; but no sand is to be laid upon the rough plaster-work. The method of extra-lathing may be applied to cieling joists, to sloping roofs, and to wooden partitions.

The third method, which is that of inter-securing, is very similar to that of under-flooring; but no sand is afterwards to be laid upon it. Inter-securing is applicable to the same parts of a building as the method of extra-lathing, but it is seldom necessary.

Lord Mahon has made several experiments in order to demonstrate the efficacy of these methods. In most houses, it is only necessary to secure the floors; and the extra-expence of under-flooring, including all materials, is only about nine pence per square yard; and with the use of quick-lime a little more. The extra-expence of the method of extra-lathing is no more than six pence per square yard, for the timber, side-walls, and partitions; but for the ceiling, about nine pence per square yard. But in most houses, no extra-lathing is necessary. *Phil. Transf. vol. lxxviii. for 1778, part ii. art. 4. p. 884, &c.*

Flame

FLAME, (*flamma*, Latin,) is the actual burning, attended with heat and light, of a volatile combustible substance; and this substance may be either a comminuted solid, (*viz.* a powder,) or a vapour, or a gas.

The powder of rosin, and of other brittle resinous bodies, the farina of several plants, and some other powdered combustibles, when projected through the flame of a candle, or of a piece of burning paper, instantly take fire, and the flame spreads through the whole powdery cloud. Powders of this sort are used at the play-houses for representing a flash of lightning or other sudden light. Powdered rosin, and the powder of lycopodium, have been found to produce this effect equally well; yet the latter, when it may be procured, is by far preferable to the former, and that on account of its being an unadhesive light powder, easily brushed off from any thing, whereas the powdered rosin sticks to, and soils every thing that it happens to fall upon.

The vapour of certain inflammable fluids, such as spirit of wine, ether, spirit of turpentine, &c. are instantly inflamed by the contact of a candle, or other flaming body, or by a spark of electricity, and continue to burn as long as there is a sufficient supply of it.

The inflammable gases, when they are extricated either by the action of heat, or otherwise, from substances that contain them, may also be inflamed, and will burn in a similar manner. Thus, if iron filings and diluted sulphuric acid be placed in a bottle, an effervescence takes place, together with a copious production of hydrogen gas, which comes out in a stream from the aperture of the bottle, and it may be inflamed either by a lighted candle, paper, wood, &c. or by passing an electric spark through it. Thus also, when coals are lighted in a common fire, the heat softens their bituminous parts, and expels the inflammable gases, which burn and constitute the flame, as every body must daily experience. But besides the inflammable gases, heat expels from coals an aqueous vapour, a thick fluid like tar, and some gases that are not of a combustible nature, and those products are neither equal nor constant, that is, sometimes some of them predominate, and sometimes the other. The consequence of which is, that the flame of coals is continually wavering both in shape and intensity of colour. It frequently shifts from one place to another, and what gave a beautiful white light a few seconds before, has become a stream of dense and dark smoke. It may be hardly worth observing that the changeable inclination of the flame is owing to the motion of the air, which runs towards the fire in various directions.

The like thing takes place in the combustion of wood, and vegetable matter in general. The heat extricates the volatile and inflammable materials which take fire, and produce the flame.

In the combustion of charcoal, and of coak, (*viz.* charred mineral coal,) the flame and the smoke are very trifling, because the operation of charring has previously expelled from those materials a great portion of their volatile ingredients.

With respect to the process of the combustion, the same requisites are necessary with the combustion of volatile substances, which produce the flame, as with the combustion of solids; *viz.* the combustible must be heated to a certain degree, a fire must be communicated, and the combustion can only take place in contact with oxygen gas, or with substances which contain oxygen. See COMBUSTION.

Thus, we have given a general sketch of the nature of flame; but there are several remarkable particulars belonging to every part of the above mentioned process, which are highly deserving of notice, and which, of course, we shall now endeavour to point out successively.

The purposes for which mankind employs fires, or combustion in general, are either for the use of the heat, or for the use of the light. The heat is subservient to the numerous and important purposes of cooking victuals, of warming apartments, and thus rendering inhabitable such climates, as otherwise the human species could not live in; of giving existence to all metallurgic operations, to the making of glass, of lime for building, &c. &c. The light is subservient to purposes equally important. In short, it enables human beings to follow their operations, during the absence of the day-light nearly, if not full as well, as in the day-time. The flame of a single candle animates a family; every one follows his occupations, and no dread is felt of the darkness of night. Were it not for artificial light, how great a portion of the advantages of industry, and of real comfort, would the human species be deprived of.

When heat is wanted, then rough solid combustibles are used which give it in abundance, and at a cheap rate; but when light is wanted, then the purest and the most uniform combustibles must be used, otherwise an inadequate effect is produced, and a considerable quantity of materials is expended. In some uncivilized countries, slender faggots of some kind of resinous wood are used by way of candles. When lighted at one end they burn gradually, and afford a good deal of light, but it is unsteady, and encumbered with a good deal of smoke. Besides, these faggots are readily burnt out, and must be quickly replaced by new ones.

At present, in all civilized countries, the principal com-

combustibles that are used for the production of a bright and luminous flame, are wax, the fat of animals, under the general name of tallow, oil, either of fish or of vegetables, and the inflammable gas of coals, which has but lately been introduced, at least in this country. The extensive consumption of these materials, and the successive increase of their price, has obliged the industrious to devise the best means of producing the greatest effect with the least possible quantity of materials.

Wax, tallow, and oils must be rendered volatile before they will produce a flame, but for this purpose it is sufficient to volatilize a small quantity of any of them, successively; for this small quantity will suffice to give a useful flame, and hence we must admire the simple, yet wonderful contrivance of a common candle or lamp. This contrivance contains a considerable quantity of the combustible substance, sufficient to last several hours; it has likewise, in a particular place, a slender piece of spongy vegetable substance, called the *wick*, which in fact is the fire place, or laboratory where the whole operation is conducted. The wick which, in the formation of the candle, or preparation of the lamp, has been partly or entirely soaked in the wax, or tallow, or oil, is set fire to by the approach of some other substance actually burning; this heat renders volatile and inflames that part of the wax, oil, &c. which is in the wick, and at the same time softens that which is next to it; the first portion of the wax, &c. being thus consumed, the wick is, in consequence of its capillary attraction, enabled to imbibe more materials for the maintenance of the flame, and so on in succession until the whole is exhausted.

There is a circumstance frequently attending the first lighting of a candle, which demands a short explanation in this place. It is, that at first the candle sometimes burns dimly, and looks as if it would go out. The method of reviving the flame in such cases is to lift up the candle perpendicularly with a quick motion, three or four times successively, which immediately revives the light. The reason of the first dimness is that the wax or tallow, by being too cold or too hard, is not melted by the combustion of that small portion which is in the wick, and of course cannot supply the waste of the wick; but by the lifting up of the candle, the air beats down the flame upon the wax or tallow adjoining to the wick, which melts it, and enables it to run up into the pores of the wick, where it is rendered volatile, and is inflamed, &c.

That part of the combustible which is successively rendered volatile by the heat of the flame is not all burnt, but part of it escapes in the form of smoke through the middle of the flame, because that part cannot come in contact with the oxygen of the surrounding atmosphere; hence it follows, that with a large wick and a large flame, this waste of combustible matter is proportionately much greater than with a small wick and a small flame. In fact, when the wick is not greater than a single thread of cotton, the flame, though very small, is, however, peculiarly bright, and free from smoke; whereas in lamps with a very large wick, such as are often suspended before butcher's shops, or with those of the lamp lighters, the smoke is very offensive, and in great measure eclipses the light of the flame.

In order to avoid this inconvenience, the ingenious Mr. Argand made that famous contrivance of a lamp, which now justly goes by his name. He made the burner or wick thin and circular, with a free passage for the air through the middle. In this construction a very thin and circular flame comes in contact with a vast quantity of air both within and without the circle, in consequence of which none of the volatilized oil escapes without burning, and the flame

is very brilliant and active. This shews the reason of what is commonly said of this lamp, namely, that it consumes its own smoke. With respect to the original construction, and the successive improvements of this admirable lamp, we must refer the reader to the article *LAMP*.

Instead of a circular form, the wick has also been made thin and oblong; but though this construction has some advantage over the common lamp, yet it is far inferior to Argand's. A circular or an oblong wick has likewise been tried in wax or tallow candles, but the attempts have not been attended with any remarkable advantage.

Another consequence of the want of oxygen in the middle of the large flame of a lamp or candle, is the formation of a coaly concretion at the extremity of the wick. This arises from the coaly or grosser particles of the combustible which are too heavy to become volatile, and at the same time do not come in contact with the oxygen which is necessary for their combustion; hence they accumulate and spread out somewhat like a fungus. If the wick be inclined a little, so that the end of it may just project out of the flame, which always goes straight upwards; then no coaly concretion is formed. In the lamps which illuminate the streets of London, the wick lies nearly horizontal, in consequence of which they seldom contract any coaly concretion.

Of the three principal materials for producing a useful bright flame, *viz.* wax, tallow, and oil, the first and second are mostly used within doors in this country; but the fish oil, the combustion of which is attended with an unpleasant smell, is mostly used for street lamps and other out of doors purposes; excepting indeed when Argand's lamps are used, for in these the oil gives no bad smell. Oil of olives burns without any offensive smell; therefore much use is made of it for lamps in private houses in those countries where it may be had at a cheap rate, as in Italy, the south of France, &c.

Besides the above, a new material has of late been attempted to be introduced in this country, for the purpose of lighting houses, streets, manufactories, &c. the material is the inflammable gas of coals. Every body must know, that when coals are burning in a common fire place, a flame more or less luminous (according as it is more or less encumbered with incombustible smoke and vapour) issues from them; and they frequently emit some very beautiful streams of a flame remarkably bright. All this, as we have already mentioned, arises from the gases which are extricated from the coals by the heat. It was natural to imagine that such gas might be received in proper reservoirs, and might afterwards be forced out of small apertures, which being lighted might serve, as the flames of candles, to illuminate a room or other place. The trial was easily made, and it was attended with the desired effect. The principle of the apparatus and of the operation is as follows: The coal is placed in large iron vessels, called retorts, to the apertures of which iron pipes are adapted, which terminate in a vessel, or vessels, called gasometers, or reservoirs, which are inverted in water. The retorts thus charged are placed upon the fire, the action of which extricates the gas from the coals that are within the retorts, together with an aqueous vapour, a thickish fluid, or tar, &c. These products are conveyed through the above-mentioned pipes under the gasometers where the gas is washed, and remains ready for use. There are then other smaller pipes from the gasometer, which branch out into smaller ramifications, until they terminate into the places where the lights are wanted. The extremities of the pipes have small apertures, out of which the gas issues, and the streams being lighted at those apertures, will burn with a clear and constant flame as long as the supply of gas continues. All the pipes which come from the

gasometer are furnished with stop-cocks, in order both to prevent the useless waste of gas, and to regulate the sizes of the flames.

The method of producing the gas being thus contrived, the next step was to determine how far such lights might be employed, consistently with expence, safety, &c. A few shops in London were lighted with it, but the use was soon discontinued, as it was said, principally on account of the unpleasant smell. A proposal, and some attempts were made for lighting some of the streets of London by means of this coal gas; but either the mysterious nature of the proposals, or the expence attending the operation, or some other cause of obstruction, has not as yet allowed the adoption of the plan. Other attempts of the like nature have been made elsewhere, but of their successes we have no authentic account; excepting however of one, which was laid before the Royal Society by the operator, Mr. Murdock, and is published in the Philosophical Transactions for the year 1808. The precision with which the particulars are stated in Mr. Murdock's account, and the essential use of which such statements may be to a vast number of persons, who are now engaged in similar examinations in this new branch of civil economy, induce us to transcribe the most essential part of the account in the present article; reserving to add what future improvements may come to our notice to the article *Gas Lights*.

"These facts and results, Mr. Murdock says, were made, during the present winter, at the cotton manufactory of Messrs. Philips and Lee, at Manchester, where the light obtained by the combustion of the gas from coal is used upon a very large scale; the apparatus for its production and application having been prepared by me at the works of Messrs. Boulton, Watt, and Co. at Soho.

"The whole of the rooms of this cotton mill, which is, I believe, the most extensive in the united kingdom, as well as its counting-houses and store-rooms, and the adjacent dwelling house of Mr. Lee, are lighted with the gas from coal. The total quantity of light used during the hours of burning has been ascertained, by a comparison of shadows, to be about equal to the light which 2500 mould candles, of six in the pound, would give; each of the candles with which the comparison was made consuming at the rate of 4.10ths of an ounce (175 grains) of tallow per hour.

"The burners are of two kinds: the one is upon the principle of the Argand lamp, and resembles it in appearance; the other is a small curved tube with a conical end, having three circular apertures or perforations, of about a thirtieth of an inch in diameter, one at the point of the cone, and two lateral ones, through which the gas issues, forming three divergent jets of flame, somewhat like a fleur-de-lis. The shape and general appearance of this tube has procured it, among the workmen, the name of the cockspur burner.

"The number of burners employed in all the buildings amounts to 271 Argands, and 633 cockspurs; each of the former giving a light equal to that of four candles of the description above-mentioned; and each of the latter a light equal to two and a quarter of the same candles; making therefore the total of the gas light a little more than equal to that of 2500 candles. When thus regulated, the whole of the above burners require an hourly supply of 1250 cubic feet of the gas produced from cannel coal; the superior quality and quantity of the gas produced from that material having given it a decided preference in this situation over every other coal, notwithstanding its higher price.

"The time during which the gas light is used may, upon an average of the whole year, be stated at least at two hours

per day of 24 hours. In some mills, where there is over work, it will be three hours; and in the few where night work is still continued nearly twelve hours. But taking two hours per day as the common average throughout the year, the consumption in Messrs. Philips' and Lee's mill will be $1250 \times 2 = 2500$ cubic feet of gas per day; to produce which 700 weight of cannel coal is required in the retort. The price of the best Wigan cannel (the sort used) is $13\frac{1}{2}d.$ per cwt. ($22s. 6d.$ per ton) delivered at the mill, or say about eight shillings for the seven hundred weight. Multiplying by the number of working days in the year (313), the annual consumption of cannel will be 110 tons, and its cost 125*l*.

"About one-third of the above quantity, or say forty tons of good common coal, value ten shillings per ton, is required for fuel to heat the retorts, the annual amount of which is 20*l*.

"The 110 tons of cannel coal, when distilled, produce about 70 tons of good coak, which is sold upon the spot at $1s. 4d.$ per cwt. and will therefore amount annually to the sum of 93*l*.

"The quantity of tar produced from each ton of cannel coal is from 11 to 12 ale gallons, making a total annual produce of about 1250 ale gallons, which not having been yet sold, I cannot determine its value.

"The interest of the capital expended in the necessary apparatus and buildings, together with what is considered as an ample allowance for wear and tear, is stated by Mr. Lee at about 550*l*. per annum, in which some allowance is made for this apparatus being made upon a scale adequate to the supply of a still greater quantity of light, than he has occasion to make use of.

"He is of opinion that the cost of attendance upon candles would be as much, if not more, than upon the gas apparatus; so that, in forming the comparison, nothing need be stated upon that score, on either side.

"The economical statement for one year, then, stands thus:

Cost of 110 tons of cannel coal	-	-	£ 125
Ditto of 40 tons of common ditto	-	-	20
			<hr/>
			145
Deduct the value of 70 tons of coak	-	-	93
The annual expenditure in coal, after deducting the value of the coak, and without allowing any thing for the tar, is therefore	-	-	52
And the interest of capital, and wear and tear of apparatus	-	-	550
Making the total expence of the gas apparatus per annum, about	-	-	600

"That of candles, to give the same light, would be about 2000*l*. For each candle, consuming at the rate of 4.10ths of an ounce of tallow per hour, the 2500 candles burning, upon an average of the year, two hours per day, would, at one shilling per pound, the present price, amount to nearly the sum of money above-mentioned.

"If the comparison were made upon an average of three hours per day, the advantage would be still more in favour of the gas light.

"At first, some inconvenience was experienced from the smell of the unconsumed, or imperfectly purified gas, which may in a great measure be attributed to the introduction of successive improvements in the construction of the apparatus, as the work proceeded. But since its completion, and since the persons to whose care it is committed have be-

some familiar with its management, this inconvenience has been obviated, not only in the mill, but also in Mr. Lee's house, which is most brilliantly illuminated with it, to the exclusion of every other species of artificial light.

"The peculiar softness and clearness of this light, with its almost unvarying intensity, have brought it into great favour with the work-people. And its being free from the inconvenience and danger resulting from the sparks and frequent snuffing of candles, is a circumstance of material importance, as tending to diminish the hazard of fire, to which cotton mills are known to be much exposed."

In the burning of candles or oil lamps, the heat of the flame softens and attenuates the materials, and converts them partly into an elastic fluid which takes fire successively and maintains the flame. In the burning of coals, wood, turf, &c. various gases, as well as vapours, are extricated from them, but these products are not all combustible; therefore those which are not combustible tend to check the activity of the flame which arises from the combustion of the others. The gases which are principally extricated from the above-mentioned materials are hydrogen gas, azotic gas, and carbonic acid gas; the first of which only is highly inflammable in all its combinations; and it is hardly ever yielded pure by any of the above-mentioned materials. Its usual combinations are either with sulphur, or with carbon, or with phosphorus; hence it derives the denominations of sulphurated, carburated, or phosphorated, hydrogen gas.

The flames of different combustibles are not all attended with an equal production of heat and light. Sulphur burns with a weak flame; phosphorus with a very dense one. Spirit of wine burns with a very slight flame in point of light, but a very powerful one with respect to heat; so that if an Argand lamp be charged with oil, and another similar lamp be charged with spirit of wine, the flame of the latter will not have a quarter of the light of the other, but it gives more than twice as much heat as the other. The flame of spirit of wine is not accompanied with any smoke. The flame of ether is denser, but produces smoke. The flame of spirit of turpentine is attended with a very dense smoke. The flame of pure hydrogen is very faint. This flame of hydrogen produces a remarkable phenomenon, which deserves to be mentioned in this place.

If a phial, containing the materials proper for the production of hydrogen gas, (*viz.* iron filings and diluted sulphuric acid,) be furnished with a tube having a small aperture for the exit of a stream of the gas, and if this stream be lighted, a flame will continue to burn at that aperture as long as the materials continue to give out the gas. Now, if a glass tube of about an inch in diameter, and about a foot long, be held straight up, with its aperture just over the above-mentioned flame, a sound will be heard, somewhat like a delicate sound of an organ pipe. This sound varies according to the size of the tube. No very satisfactory explanation has, as yet, been given of this singular phenomenon.

The flames of volatile combustibles that are more compound in their nature, vary considerably with respect to the intensities of their heat and light. A curious phenomenon takes place in uniting the flames of two candles, *viz.* the light is considerably increased. Let a person hold two candles before his face, at first separate, and then with their flames joined. Upon the junction of the two flames, his face will appear much more illuminated than it was before. "It is conjectured," Dr. Priestley says, "that the union of the two flames produces a greater degree of heat, and that this causes a farther attenuation of the vapour, and a more copious emission of the particles of which light consists."

The effects which we have just been enumerating are such as take place in common atmospheric air.

The various colours of the flames of simple and compound bodies are likewise highly deserving the attention of philosophers. Certain combustibles, even of the purest kind, burn with flames having peculiar tints; but much stronger colours may be communicated to their flames by the admixture of various substances, especially of salts that are of an earthy or metallic nature.

The flame of a common candle is far from being of an uniform colour. The lowest part of the flame is always blue; and when the flame is sufficiently elongated, so as to be just ready to smoke, the tip is always red.

As for the colours of flames that arise from coals, wood, and other usual combustibles, their variety, which hardly amounts to a few shades of red, or purple, intermixed with the bright white light, seems principally to arise from the greater or less admixture of aqueous vapour, dense smoke, or, in short, of other incombustible products.

Spirit of wine burns with a blueish flame. The flame of sulphur has nearly the same tinge. The flame of zinc is of a bright white. The flame of most of the preparations of copper, or of the substances with which they are mixed, is greenish-blue. Spirit of wine, mixed with common salt, burns with a very unpleasant effect, as may be experienced by looking at the spectators who are illuminated by such light. If a spoonful of spirit of wine and a little boracic acid be stirred together in a cup, and then be inflamed, the flame will be beautifully green. If the spirit of wine be mixed with a little strontian earth in powder, or with any of its saline preparations, it will afterwards, on being inflamed, burn with a red, or rather purple flame. If the spirit of wine be mixed with barytes, its flame will have a beautiful yellow appearance. Such are the principal means of colouring flames, the admixture of various other substances will also impart some shades of colour to flaming bodies, but not nearly so strong as the above.

Some years ago an elegant and curious exhibition, under the title of "Philosophical Fire-works," was shewn in London by an industrious foreigner, named Diller. The exhibition consisted of the flames of certain gases or vapours which issued out of a variety of small apertures at the ends of short tubes, which were disposed in the forms of wheels, pyramids, spirals, tridents, &c. Out of these apertures the flames were gradually made to increase and decrease alternately; so that sometimes the room looked as bright as if it were illuminated by the sun, and at other times the flames would be barely discerned. But the most pleasing effect arose from the colours of these flames, as there were beautiful greens, yellows, reds, purples, &c. Mr. Diller died, and it seems that he did not leave the secret of the preparations behind him; for no one has since been able to exhibit any thing equal to those philosophical fire-works. The smell of ether, which predominated in the exhibition room, seemed to shew that Mr. Diller made great use of that liquid.

The combustible vapours and gases are not all inflamed with equal readiness. Hydrogen gas may be inflamed not only by the contact of another flaming body, but even by a very small electric spark. An electric spark a little more powerful will fire spirit of wine and ether, especially when those fluids are a little warm. Spirit of turpentine, and some essential oils may be inflamed, not only by the above-mentioned means, but even by the action of cold acids. Put about a spoonful of oil of turpentine in a cup, and pour over it about half that quantity of strong nitrous acid previously mixed with a few drops of sulphuric acid. The oil

of turpentine will immediately burst out into a flame merely in consequence of the action of the acid.

The thick fat oils must be heated to a considerable degree, and in that state a flaming body must be brought in contact with their vapour, before they will be inflamed. Even when raised to a very high temperature, they seldom will of themselves burst out in a flame. If a vessel containing oil be set upon a fire, a smoke or vapour begins to rise from it, which grows by degrees denser and denser; and at last it begins to shine in some places near the surface of the oil, somewhat like an electric light; yet it does not flame; but if in this state a flaming body, like a candle, a match, &c. be brought within the vapour, the latter will be instantly inflamed, breaking out with a sort of explosion, and will continue to burn until the oil is in great measure consumed.

Besides the use of their light, the flames of candles, and especially of lamps, are often used for the sake of the uniform heat which they give; and when no very great degree of heat is wanted, the use of such flames must be allowed to be incomparably more commodious, and more economical than a common fire. The enameller, the mineralogist, and the philosophical instrument makers, make great use of the heat of candles and lamps, the flames of which they frequently urge by means of the blow-pipe. An Argand lamp, especially when charged with spirit of wine, (for which purpose, however, the lamp must be made in a particular manner,) instead of oil, forms a pretty powerful furnace for small distillations, decoctions, &c. but even the flame of a single common lamp is sufficient for a great variety of delicate purposes.

The word flame, besides its true meaning, which we have already explained, and which denotes the combustion of a

volatile combustible body attended with the emission of heat and light, has often been indiscriminately applied to every kind of luminous appearance, provided its light had a pretty evident degree of intensity. Thus all phosphorescent bodies, electrical light, northern lights, &c. have been called flames by a variety of writers. Certain phenomena really have much the appearance of true flames; yet their real nature has not been sufficiently investigated. Thus the *ignis fatuus*, or *Jack-a-lantern*, is supposed to be nothing more than phosphorated hydrogen, which being extricated from certain materials in particular places, comes out of the ground, and burns on the surface of it; for it is a property of that gas to take fire of itself the moment it comes in contact with respirable air. The nature of those appearances in the sky, which have been called flames, is mostly unknown to us. See METEORS, and *IGNIS fatuus*.

By some authors, flame is defined to be *light emitted from fire*; by others, who have followed Newton, flame is said to be a vapour heated red-hot; for Newton in his Optics says, "Is not flame a vapour, fume, or exhalation heated red-hot, that is, so hot as to shine? For bodies do not flame without emitting a copious fume, and this fume burns in the flame."

With respect to the first definition, we imagine that the preceding part of the present article has clearly shewn that not all the light which is emitted from a fire is flame; and such for instance is the light emitted from a red-hot cinder, or of a coal nearly exhausted of its gas. As for sir I. Newton's query, it may be justly said, that the state of chemical knowledge at his time could not furnish him with better ideas respecting the nature of flame.

Flint

FLINT, *Silex cretaceus*, Linn. *Igniarius*, Carth. et Wall. *Pyromachus*, Wern. *Quartz-Agathe pyromaque*, Haüy. *Feuerstein*, Germ. *Flinta*, *Böfs-flinta*, Swed. *Pierre à feu*, Fr.

The flint, one of the most remarkable of the siliceous stones, has frequently been confounded with other hard stones of the same class; the quality it possesses in an eminent degree of giving sparks with the steel, and the popular denomination it has thence derived among almost all nations, have been the principal causes of this confusion, which may

easily be avoided by a proper attention to its more distinguishing characters. It must, however, be confessed, that, in some cases, its diagnosis is rendered uncertain by its too great affinity to *Hornstone* and *FLINT slate*, (see those articles,) and by its gradual transition into these kindred stones.

Its colour is chiefly grey, of which yellowish, blueish, and smoke-grey, are the more usual shades, and these pass, the latter into greyish-black, the former into all the well known tints of yellow, red, and reddish-brown, that approach it, to the carnelian. It is sometimes found perfectly black,

and also displaying several of the just-mentioned colours in stripes, zones, and spots.

Flint occurs massive, in angular pieces of various size, in globular boulders, frequently tapering at one end, (the petrified melons of Mount Carmel, vulgarly so called, belong to this variety): also in knobbed, branching, amorphous, perforated pieces, and as hollow balls filled with various substances. (See GODE.) Besides these forms, it sometimes adopts those of crystals, which however do not belong to it, as some writers have supposed, but are supposititious: from calcareous spar it derives the double three-sided pyramid, as also the six-sided prism acuminate by three planes; and it has been likewise observed in crystals formed after those of lamellar barytes or caulk. It is also frequently observed, (contrary to what we know of hornstone,) in extraneous external shapes, as petrifications of species of echinus, madrepora, coral, &c. Surface little glistening, and of various degrees of smoothness, often coated by, and passing into, a white or yellowish-white crust, of which we shall say more hereafter. Fracture conchoidal, never perfectly splintery; internal surface but little glistening, or dull, of an almost imperceptibly fine grain. Fragment sometimes tabular, very sharp-edged, and more or less translucent in proportion to the lighter or deeper colours of the stone. It is easily frangible. Its hardness appears to be in a ratio with the depth of its colours: in general it will scratch quartz.

Specific gravity, according to Gellert, 2.581; Blumenbach 2.594; Gmelin 2.999. To these physical characters of flint we may add the one afforded by its phosphorescence, and the peculiar smell, which are manifested when two pieces are rubbed together.

Flint is infusible before the blow-pipe without addition, but loses its colour and becomes opaque. By the intense heat excited by a stream of oxygen gas, Mr. Ehrmann found it to melt into a white glistening quartz-like globule. Its constituent parts are,

	Klaproth.	Vauquelin.	Wiegleb
Silica - -	98.00	97.0	80
Lime - -	0.50	0	2
Alumine - -	0.25	1	18
Oxyd of iron - -	0.25		
Loss - -	1.00	2	0
	<hr/> 100	<hr/> 100	<hr/> 100

Flint is met with in most parts of Europe, particularly in the north of France, in England, Saxony, Tyrol, Podolia, &c. Norway seems to be destitute of flint, as it is of chalk; also in Sweden it is scarce. In Denmark it is principally at Wordenborg and Taxøe, in the island of Seeland, that some chalk-hills with imbedded flints are found; and more copiously in the remarkable Steevens-Klint. It occurs but seldom in primitive mountains, and when found there, only in veins, as, for instance, in the Saxon Erzgebirge. Its principal geognostic situation is in flint-mountains, where it occurs chiefly in common compact lime-stone or in chalk; in the sand-stone formation, where it is also met with in the shape of those conglomerates vulgarly called *Pudding-stone*. See this article.

Though the formation of flints is a subject which has engaged the attention of many naturalists, yet but few opinions have been broached respecting it that will at all stand the test of closer investigation. The theory which explains their origin by a metamorphosis of one earth into another, though it may appear absurd to the chemist who is unable

to produce the same changes in his laboratory, has notwithstanding had its able and celebrated defenders. Some have endeavoured to prove that the argillaceous, others, that the calcareous earth, underwent this conversion into flint. Buffon was an advocate for the argillaceous origin of this stone; and the observations of Pallas appeared to corroborate the opinion of the French naturalist; for he found that the *Ephemera boraria*, which abounds in the Moskua, had in some places perforated the clayey bottom of this river with innumerable tubes closely joined; and in the adjacent fields pieces of perfect flint frequently occurred that were pierced precisely in the same manner as the clay, from which they were not found to differ in any respect but in fracture and hardness. In the same manner he states that, in the small river Sunghir, near Woldemir, black, globular, rolled masses occur, which, on being broken, exhibit, from their circumference to the central part, a gradual transition from real clay and clay-stone into what he considers as perfect flint. With all deference, however, to the great merits of this excellent observer, we cannot but see in his account one of those frequent cases in which hard stones of the siliceous class (and clay stone and Jasper belong to it) have been mistaken for real flint merely by reason of their giving copious sparks with steel: for this appears to be the character on which Pallas has chiefly founded his diagnosis of the stone he describes.

According to other geologists, it is lime-stone, and principally chalk, which have undergone a transformation into flint: an opinion which Wallerius endeavoured to support both by geognostical and chemical facts, and which was followed by Linnaeus himself. Alfo Gillet-Laumont and Girod-Chantrans, from observations they respectively made in various parts of France, were induced to consider flint as a mere modification of chalk. The principal ground on which this hypothesis appears to rest is the geognostic relationship that subsists between the strata of chalk and of flints, together with the intimate union of the boulders of flint and their white earthy crust; both these substances being to completely incorporated with one another, as to preclude the possibility of our ascertaining the line where each may be considered as perfectly distinct from the other. This latter reason, though specious, may, however, lose much of its force by future analysis of that white earthy substance. To us it appears that most of the boulders of flint, such as they are found embedded in chalk, are but seldom furnished with a coating throughout calcareous: it seems to be composed of a twofold crust, viz. an outer chalky one, originating from the matrix of the stone; and an inner one passing over into the outer, and, by reason of the similarity of colour, not distinguishable by the eye. This inner crust shews no effervescence with acids; it appears to be siliceous, and may perhaps be properly looked upon as the result of incipient decomposition; especially if it be considered that flints with uncoated surface, by a long exposure to the influence of moisture and other atmospheric agents, have been known to acquire another thin coating, (but not calcareous,) with loss of weight.

Many geologists of the present day, who consider the idea of a transmutation of the calcareous into siliceous earth as unworthy the advanced state of modern chemistry, at the same time that they are unwilling to have recourse to floods and other revolutionary agents for rolling fragments of flint into boulders, and disposing them in the regular manner in which they are now found, have adopted, some, the hypothesis of infiltration by means of a siliceous fluid; others, that of a forcible injection of melted flint into vacuities previously existing in the calcareous strata. But either of these

theories is open to objection; and, indeed, the same objections appear to apply to both. It is difficult to account for the strange predilection the stinty fluid (whether its fluidity proceeded from water or fire) has manifested for stetz lime-stone, particularly for chalk; while other stetz and primitive rocks, several of which must be supposed to have been equally exposed to it, remained perfectly untouched. Nor is it much easier to conceive how that supposed fluid can have found its way into so many approximate, but perfectly distinct, hollows in the chalk, without more or less penetrating the intermediate parts, or leaving traces of masses that were connected with the nodules as they now appear; not to mention the improbability that so many almost contiguous vacuities (especially those that must be supposed to have been the moulds for the frequently occurring tabular expansions of flint) should not have yielded to the pressure of the superincumbent stratum. As, moreover, these hypotheses are silent respecting the origin of this stinty mass, (although a substance so different in its appearance from common flint), another theory of the generation of the nodules of flint has been proposed, which, however, is not likely to meet with any followers among those geologists, whose exalted ideas of the present state of chemical knowledge lead them to suppose that the result of their analytical and synthetical processes must of necessity, in all cases, square with those great operations that, with her ample means, and assisted by a long series of ages, have been accomplished by Nature in the vast laboratory of the earth. We allude to the hypothesis, according to which all flint, whether it be found in nodules or as flat tabular plates, originates from the flesh of a stratum of marine gelatinous animals, which perished by some revolution, and were buried in their shells. The internal aspect of the nodules, and their being almost constantly found imbedded in stetz lime-stone, which, by most geologists, is allowed to owe its existence to shells and other calcareous coverings of testaceous animals, seems first to have suggested this new idea; which, strange as it appears, may be allowed to have as much plausibility as any of the former; especially as it may be adapted equally well to the system of an igneous, and to that of an aquatic origin of terrestrial bodies. Mr. Patrin is of opinion, that when the chalk was deposited at the bottom of the sea, in those strata which we now see, it met, on other strata already existing, a vast number of marine bodies, shells, madreporæ, &c. while others were carried along with the precipitating chalk itself, such as medusæ, &c. whose soft and gelatinous bodies, while they occupy much space, contain but little substance. When all these marine animals were buried in the chalk, and their decomposition took place, those of a consistence merely gelatinous left in their matrix an empty space, nearly equal to the space they occupied when alive: their substance, almost in a state of fluidity, was absorbed by the porous sides of the cavity; and by the combination of this animal fluid with the chalk, these sides were, by some unknown agent, converted into flint. In this manner Mr. Patrin accounts for the generation of nodules that are either hollow or filled up with chalk; which latter may have been deposited there by means of some aperture, or may have penetrated through the stinty coat itself, when still in a state of softness. As to those nodules, the central part of which is of a more perfectly stinty nature than that nearer the circumference, they were, according to the same author, formed of marine animals of more consistence or solidity; and it is in these particularly that vestiges of animal organization are found. The more consistent part of the body of these animals produced the

more perfect flint, such as we see it in such solid nodules; while the fluid which escaped from the body, by the effects of decomposition, formed the external layers of this nucleus, which, being mixed with the substance of the chalk, became less perfect flint the farther it removed from the central part. According to this explication, the most imperfect part of a nodule of flint would be that, which, in its original situation, occupied the lowest place, and towards which the fluid which escaped from the more solid nucleus must naturally have taken its direction. This, however, is never found to be the case; nor has Mr. Patrin endeavoured to account for that circumstance. What appears to be much in favour of this explanation is, that the whole body of echini in their shells has been found converted into flint; and Gillet-Laumont has frequently observed that those echini, which he met with in the chalk strata of Montreuil-sur-Mer, were furnished with a stinty appendage issuing from their mouths, and which appears to have been the animal substance converted into a fluid state by decomposition. The same circumstance is not seldom observed in bivalve shells, whose gelatinous inhabitants have been found in a perfectly siliceous state; while the shells themselves had retained their original calcareous nature, and were partly converted into spar. In cases where the gelatinous marine bodies were in such abundance that no intermediate space was left for the deposition of chalk, the flint has been formed into large masses and plates of considerable extent. Dr. Darwin's ideas on this subject are nearly the same, and modified only by his adopting a different theory for explaining the conversion of the gelatinous animals into flint. He conjectures that the nodules of flint found in chalk-beds have gained their form, as well as their dark colour, from the flesh of the shell-fish from which they had their origin, but which have been so completely fused by heat, or heat and water, as to obliterate all vestiges of the shell; in the same manner as (according to the doctor's opinion) the nodules of agate and onyx were produced from parts of vegetables, but which had been so completely fused as to obliterate all marks of their organization.

A remarkable circumstance, relating to the geological history of flint, should not be passed over unnoticed in this place: it is that Sir Henry Englefield has observed in the neighbourhood of Carisbrook, and in other parts of the Isle of Wight, an immense number of nodules of flint, all of which, though not removed out of their places, and retaining perfectly their original shape, were more or less burst or shattered. Some few were only split into large pieces, but the greater part were broken into small fragments, and some absolutely reduced to impalpable powder. The chalk strata in which they were imbedded had an inclination of at least 67 degrees, and perpendicular fissures traversed the whole. Sir Harry conjectures, "that when the tremendous convulsion took place which sunk them to the situation in which they now appear, (at which time the channel which separates the Isle of Wight from the main land was perhaps formed,) the strata of chalk, in the act of subsidence, had a tendency to slide on each other; and this would be exerted most sensibly where, from the admixture of the flints, the cohesion of the parts of the chalk was the weakest. This motion, or rather strain of so enormous a weight, might in an instant shiver the flints, though their resistance stopped the incipient motion; for the flints, though crushed to powder, are not displaced, which must have been the case had the bed slipped sensibly." This theory appears to us very unsatisfactory, though we are not prepared to give a better. The advocates for the igneous origin of flint may,

perhaps, be inclined to account for the phenomenon by an accidental sudden cooling of the flinty masses.

We conclude this article by adding a few words on the *uses* to which flint is applied, some of which are of considerable importance. The one derived from its giving copious sparks with steel is the most ancient and generally known; but the art of cutting or rather breaking this stone into regularly shaped gun-flints is of more modern date, and was not practised till a considerable time after the invention of fire-arms. The mode of making gun-flints has for a long time been involved in fable and mystery: the most absurd and contradictory accounts having been given of it by various authors; and it was not till lately that we have been made fully acquainted (by Hacquet of Vienna, and by Dolomieu) with the simple manner in which these flints are manufactured in Galicia and in France, where they constitute an important article of trade. (See GUN-FLINT.) The art of squaring and chipping flint was practised long before that of making gun-flints; and as this latter requires exactly the same management and the same tools, the former cannot properly be called a lost art, though, on account of the expensiveness of such square pieces of flint, if employed for constructing walls and covering roofs, it is not much practised. The north wall of the Bridewell at Norwich, mentioned in a letter of Mr. Baker, in the 43d volume of the Philosophical Transactions, was built of flints, "squared to such a nicety, that the thin edge of a knife could not be insinuated between the joints without a great deal of difficulty." And we learn from a note to that letter, that the gate of the Austin friars at Canterbury, the gate of St. John's abbey at Colchester, and the gate near Whitehall, Westminster, are executed in the same taste; and the platform on the top of the Royal observatory at Paris, which is paved with flint after the same manner, is adduced as a proof that the French have in some measure recovered the art. Flint is also often employed in the manufactory of glass, smalt, porcelain; and some of its lighter coloured and striped varieties are made use of for ornamental purposes. They take an excellent polish, and are not unfrequently manufactured into snuff-boxes, &c.

FLINT-Slate. The history of this fossil presents a labyrinth of blunders and confusion. On one hand it has been described under the names of well defined Wernerian species of rocks, such as horn-stone, trapp, &c.; on the other hand it has been jumbled together with various mineral substances, under the vague and unsystematic appellations of *roche corneenne*, *petrosilex*, and particularly (by German mineralogical writers) under that of "hornschiefer," or corneous slate. This latter was applied by some mineralogists to the subject of this article; but by others it was indiscriminately given to hornblend-slate, to varieties of clay-slate, to mica, and to porphyry-slate; whence professor Werner, to prevent the same confusion that has been introduced into mineralogy, by the term "shorl," expunged that of *hornschiefer*, (though he had made use of it himself,) applying to the fossil in question the name of *kiesel-schiefer*, now generally adopted in Germany, and of which "flint-slate" is a literal translation. The just mentioned author has divided this species into two sub-species, viz. into common flint-slate, and Lydian stone. The latter has been considered by some as a mere variety of the former; but there are good reasons for keeping it distinct. See LYDIAN STONE.

Common flint-slate occurs generally of a dark grey colour, which has frequently an admixture of blue, of red, and of yellow; and these tints often pass over into each

other, or are seen separately in the same fragments, as spots or stripes. The blood-red and brownish-red varieties are the scarcest. It is found massive and in rounded pieces; which latter have a smooth surface. Internally it is dull; now and then rather glimmering. In small fragments its fracture varies; it is sometimes splintery, and imperfectly conchoidal, and sometimes passes into even; the blackish-grey variety with the latter fracture approaches the Lydian stone. In large masses it manifests its stony nature. Its fragments are angular and sharp, and but little translucent at the edges. It is brittle, and its hardness nearly the same as that of quartz. Another pretty constant character of flint-slate is its being traversed by veins of quartz, that are often of a greyish or reddish colour. Specific gravity, according to Gerhard, 2.860; according to Kirwan from 2.596 to 2.641. Those varieties of flint-slate that have been chemically examined are not fusible *per se*; nor do they much change their colour in the fire; the grey becomes rather lighter coloured, the black does not appear to be at all affected by the heat of the blow-pipe. Wiegand's analysis of flint-slate from Fulda (in vol. i. of Chem. Annalen, where, however, it is called *hornschiefer*, and considered as of volcanic origin) has given the following result:

Silica	75.00
Lime	10.00
Magnesia	4.58
Oxyd of iron	3.54
Inflamm. particles	5.02
	98.14

Flint-slate appears to pass over into Lydian stone, into horn-stone, quartz, and particularly into clay-slate; so that when seen in small fragments, it is often difficult to seize its distinguishing characters. It is found in various parts of Germany, Bohemia, Silesia, in Bareuth, the kingdom of Saxony, the Hartz, Palatinate, Salzburg, &c.; and, according to Mr. Jameson, in various parts of the great tract of transition rocks in the south of Scotland. The geognostic relations of flint-slate are not well ascertained, and indeed it is difficult to assign it a proper place among the rocks. It is generally found in huge, cliffy, and craggy masses, particularly on granite and clay-slate, and more frequently as beds in transition, clay-stone, *grauwacke*, and *grauwacke-slate*. From the observations of some geologists it would appear that flint slate is, in many cases, to be referred to the transition rocks of Werner; and, according to Freiesleben, the specimens in Laskus's collection of rocks, which by this author are described as varieties of trapp, belong to the transition flint-slate; whence its occurring as angular fragments in grey-wacke, and as rounded pieces in the old red sand-stone can be no matter of surprise. Most frequently, however, it occurs in the shape of boulders, on plains, and in the beds of rivers.

FLINT is used, in our military service, for the purpose of affixing into a *vice* made at the top of the *cock* of a musket, or pistol lock; so that when impelled against a piece of steel, called the *hammer*, it may strike fire, and ignite the gun-powder contained in a *pan*, concealed by the *hammer*, until the latter is forced backwards on a pivot, by the great force with which the *cock* strikes against it; when it not only produces fire, but, by its peculiar form, directs the sparks towards the *priming* in the *pan*.

Flints are easily adapted to this purpose; those great masses which are found chiefly in chalky soils, being broken by hammers, yield a number of wedge-like pieces,

of which the sides are trimmed to the proper width, and the backs brought into a proper form, which should be rather concave. This concavity is, however, very little attended to, but is of great service, since it embraces the screw of the vice, and causes the flint to retain a much firmer hold than when its back is made either straight, or convex; the latter is a great fault, but is commonly overlooked.

The proper sizes for flints are as follow; for a musquet, one inch and five-eighths, for the length, with a width of an inch and a quarter; the thickness at the back one-third of an inch, and the tapering to be rather sudden than gradual, something like the end of a chisel. Such flints fit well in the vice, being previously laid in a bed of thin sheet-lead, or for want of it, in stout leather. The edge of a flint, thus formed, is far less subject to splinter, than where the angle is more acute. It may perhaps be objected, that a thin edge strikes fire better than a thick one; but that will be for only a few rounds; whereas the thicker edge resists better, and preserves an equable facility of scintillating for a long time. All military men must know that nothing is more adverse to the operations of a regiment, than the necessity (which too often occurs in consequence of the proper form not being sufficiently attended to) for men to quit their ranks for the purpose of either hammering, or changing their flints. To the brave man such a necessity is painful, as well as dangerous, while to the less resolute it serves at least for a pretext to pass into the rear, or eventually to relinquish his post altogether.

A carabine flint should be one inch and a quarter in length, by one inch in width; that for a pistol, such as is used among our military, ought to be rather more than an inch in length, by three quarters in width. In fixing them into the vice, great care should be taken that their left sides pass down clear of the barrel, which they would otherwise hack very much, and be themselves subject to splinter, while the cock itself might, by being unduly checked, be snapt at its neck.

When flints have a curve, they should always be so fixed in the vice, as to give the curve a downward direction; since, in that way, they act more forcibly, and offer the greatest resistance. Straight flints, after being so far rounded as to yield no sparks, when their chamfered sides may have been uppermost, may be again rendered serviceable by being reversed, so as to bring their flat sides uppermost. Soaking flints in water restores them partially, probably by supplying them with hydrogen, but in a very small degree, and that not permanently.

The best flints are such as, when acted upon by steel, produce strong lasting corruscations, which emit a sulphureous smell, and are sufficiently large to leave some little stain on tissue paper, or on fine lint. Such will not only be found to yield a certain fire, but to break up admirably under the hammer employed to reduce them to splinters, and to fit them for the soldier's use. On the contrary, however clear, black, and firm a flint may appear, if its sparks are not vivid, and highly sulphureous, it ought to be at once thrown aside.

The hardest flints being generally the best, experiments were made with agates, cornelians, &c. all of which produce beautiful sparks, but, being extremely brittle, could not be brought into general use; however, in situations where they are obtainable, and where flints are not to be had, they become valuable substitutes. Various attempts have been made to produce flints by means of composition; but such have always proved vitreous, and consequently weak both in substance, and in the production of sparks. We cannot conclude this article without strongly recommending,

that more attention be paid at our arsenals to the rejection of flints of defective form and quality.

Flints are generally packed in small casks, called half-barrels, each of which contains,

	Number	qrs.	lbs.
Musquet flints	2000	weighing	2 14
Carabine do.	3000		2 10
Pistol do.	4000		2 15

The tonnage of this article is computed at 28 kegs of musquet-flints to occupy 18 cwt. and 10 kegs of pistol-flints to occupy 3 cwt. 2 qrs. which our readers cannot fail to observe by no means corresponds with the foregoing table of contents.

FLINTS, in the *Glass-trade*. The way of preparing flints for the nicest operations in the glass-trade is this. Choose the hardest flints, such as are black and will resist the file, and will grow white when calcined in the fire. Cleanse these of the white crust that adheres to them, then calcine them in a strong fire, and throw them, while red-hot, into cold water; wash off the ashes that may adhere to them, and powder them in an iron mortar, and sift them through a very fine sieve; pour upon this powder some weak aqua fortis, or the phlegm of aqua fortis, to dissolve and take up any particles of iron it may have got from the mortar; stir this mixture several times, then let it rest, and in the morning pour off the liquor, and wash the powder several times with hot-water, and afterwards dry it for use. You will thus have a powder for making the purest glass, as perfectly fine and faultless, as if you had used rock crystal itself. Cramer's Art of Assaying Metals, p. 438.

The washing off the ferruginous particles with aqua fortis is not necessary when the glass intended to be made is to be tinged with iron afterwards; but when meant to be a pure white, this is the method that will secure success.

FLINTS, the small, sharp, hard, vitrifiable stones which often abound in soils of the more thin, poor kinds.

FLINTS, oil or liquor of, a name given by some to a preparation made of four ounces of flints, calcined and powdered, and mixed with twelve ounces of salt of tartar; these being melted together in a large crucible, by a strong fire, run into a glass, which quickly and strongly attracts moisture from the air, and is entirely soluble in water, except a very small portion of earthy matter; this glass, being afterwards powdered and set in a cellar, runs into an oil per deliquium; with this and the calx of any metal is prepared one of the metallic vegetations. If any acid be added to the liquor of flints, so as to saturate the alkali, the flint, which was kept dissolved in water by means of this alkali, will be now precipitated in the state of a fine earth, which earth is entirely soluble by acids.

FLINT Walls. See WALL.

FLINT Nodules, in *Geology*, are a phenomenon of a curious and important kind, when their regular dispersion through the chalk strata are taken into consideration, as well as the singular and somewhat regular shapes which they assume. The great assemblage of chalk strata which form the uppermost but two of the assemblages of strata in Britain, as far as is yet known, (*viz.* the London-clay and Bagshot-sand,) abounds with these nodules in about the upper half thereof, called the upper or flinty chalk, while the under part, called the lower or hard chalk, has few if any flints occurring in it, and these, at its upper part, if such do occur. It is well ascertained, that none of the chalk strata are entirely free of minute grains of siliceous or gritty matter in them, whence the use of chalk or whitening in scouring tin, silver, and other vessels arises; and modern observations by Mr. Smith and his pupils have shewn, that where the layers of

flints most abound, or are nearest together, as they are near to the top of the whole series, that there the intervening beds of chalk are most *free* or soft, as well as the whitest, and that from these situations it is, that the writing chalk used by carpenters, &c. and the best for the manufacture of whiting for lime for the plasterer's uses, or for chalking land by the husbandmen, are taken. It has further been observed, that as the flints decrease in quantity, in descending the chalk series, that more siliceous grains appear in the chalk itself, until the flints cease altogether, and the lower-chalk commences; which lower chalk is much harder, more like lime-stone, and is more siliceous, which properties seem to render it preferable for the common purpose of mortar-making, than the softer chalks. This hard or inferior chalk, used for lime-burning in Bedfordshire and the adjoining counties, is called hurlock; and it is observed, that the beds of this hard chalk become more hard and compact in descending the series, as was a few years ago visible to travellers in the cutting of the new road down Ruddle-Hill, a mile from Dunstable, and as may again be shewn, if the tunnel which has been proposed under the old road for avoiding the inconvenient bend occasioned by the new one, should be carried into effect. The hard chalk or hurlock continues to increase in its siliceous qualities until near the bottom of the series, where it becomes a free-stone, which is in great repute there, under the name of Totternhoe-stone, which has a sharp and fine grit, and instead of being lime-stone, possesses the properties of a *fire-stone*, under which denomination the stone of this stratum is brought to the metropolis from Ryegate, Godstone, and other places on the southern skirt of the North Downs of Surry. Thus it appears, that siliceous or flinty matter abounds in the chalk, through the whole series, from the sand strata which lie above it (at Croydon), to the sand strata which lie below it (at Ryegate); but it is in the upper part of the chalk series collected into nodules and layers of flint, and in the lower part of the series is distributed in the mass of chalk.

It seems probable, from the observations of Mr. Parkinson, and other late observers, that the flint nodules of the chalk strata, or great part of them, owe their origin, or rather perhaps occupy the place of the *Alcyonium* and others of the zoophytic tribes of the primitive creation. The vast number of hollow tubes in flint, which we meet with in the chalk pits at Harefield, near Rickmansworth, Herts, and other places, though often mistook for petrified bones, seem to us to be remains of the coralline tribe. *Echini* are often found among the flint nodules of the chalk strata, some of them large and rather of a rude shape, compared with the delicate workmanship observable on many of echinus; this kind are found in vast numbers in the chalk-pits about Brandon in Norfolk, and are used in building walls and houses, in a neat and very singular style.

FLINTSHIRE, in *Geography*, a county in North

Wales, bounded on the south and west by Denbighshire; on the north by the Irish sea; and on the north-east is separated from Cheshire by the estuary of the Dee. At an early period this district formed a portion of the country to which the Romans gave the appellation of *Ordovicia*; the inhabitants of which so eminently distinguished themselves in their pertinacious resistance to the Roman arms. Subsequent to the Romans leaving the island, it long constituted the territory known to the Britons by the name of *Deheubarth*; and several strong castles still remaining, shew it was formerly a scene of sanguinary contention. In the time of Henry VIII, when Wales was incorporated with England, this was made one of the six counties of North Wales. This county extends in length 33 miles, and in breadth from 8 to 9, containing about 160,000 acres of land, of which, according to the report to the Board of Agriculture, only 20,000 are in an arable state, 116,000 under pasturage, and the remainder in a state of waste. The principal rivers are the Dee, which rising in Merionethshire, after running through Denbighshire, washes this county, and is navigable from Chester to the sea. The Clwydd has its source in Denbighshire, and, running in a northerly direction, is joined by the Alan below St. Asaph, and falls into the Irish sea. It is also watered by the Seion, the Wheeler, and a few smaller streams. The face of the country is much less diversified than any other Welsh county. A ridge of low hills rises abruptly on the north-eastern part of the county from the Dee, and, running parallel with that river, terminates at the sea. The vale of Mold is a rich level country, and the vale, or rather valley of Clwydd, has been long celebrated for its picturesque beauty. The northern part is champagne, and abounds with corn; the vallies consist of an argillaceous soil, and are productive in grass. The cattle are small, but considered excellent milchers. Quantities of honey are annually produced, which the inhabitants manufacture into a kind of wine called *Metheglin*. The hills are barren, but are internally rich, containing free-stone, lime-stone, coal, lead, copper, and calamine, the ores of which are smelted, and the metals exported via the port of Chester. The county politically is divided into five hundreds, *viz.* Colehill, Maylor, Mold, Prestayn, and Rhyddlan, comprising one city, St. Asaph, one borough, Flint, and four other market towns, *viz.* Caerwys, Caergwrle, Mold, and Holywell; and twenty-eight parishes, 23 of which are in the diocese of St. Asaph, and five in that of Chester. By the returns made under the population act to parliament, in 1801, the number of houses was 7585, and inhabitants 39,622; out of which number it appeared 10,332 were occupied in the labours of agriculture, and 6989 employed in trade. Many of the latter find employment in the mines and smelting-houses, and others in the linen trade, a manufactory of which was, by the patriotic exertions of Mr. Fitzwilliams, introduced into the county, and has since spread, and is at present in a flourishing state. The county is represented by one member in the British senate.

Flood

FLOOD, a deluge or inundation of waters. See **DELUGE**.

FLOOD is also used in speaking of the tide. See **TIDE**.

When the water is at lowest, it is called flood; when rising, young, or old flood; when at highest, high flood; when beginning to fall, ebb-water.

FLOOD-mark, the mark which the sea makes on the shore, at flowing water, and the highest tide: it is also called high-water mark.

FLOOD Sand. See **SAND**.

FLOOD-gate, among *Engineers*, signified a gate or sluice which can be opened or shut at pleasure to retain or give passage to the water of a river liable to be swollen by floods. Flood-gates are necessary in many situations upon rivers where the water is retained for the service of mills, canals, navigations, docks, &c.; in these only a certain quantity of the stream can be employed, and the surplus in time of a flood must be suffered to escape by another passage. For instance, in the case of mills upon a large and rapid river, the stream of water is intercepted by a weir erected across it, and penned up the proper height to obtain a sufficient fall for the mill, which is situated by the side of the river, with a channel leading from above the weir, to convey the water to the mill, whilst another conducts it into the river below the weir. In ordinary times this arrangement is sufficient, for whenever the mill is not in action, the water which would otherwise pass through it, flows over the weir, and escapes into the river below. Now if the sudden falling of rain, or melting of snow, causes a flood in the river, it often happens that the length of the weir is insufficient to vent the torrent of water coming down; and without some contrivance answering the purpose of a flood gate, to give passage to the water, it becomes penned up many feet above the crown, or highest level of the weir, inundating the lands adjacent to the channel, above the weir. If the river is provided with a proper flood-gate, it acts, when open, in the same manner as removing a part of the weir, and allows the water to pass down quietly without rising much above the level which is common in ordinary times. From this, the use of a flood-gate will be comprehended; navigable rivers, which are penned up to form

locks, require flood-gates, which are applied in the same manner as before-mentioned.

Flood-gates may be constructed in various forms; but it is indispensable that they should be capable of being opened or shut during the time when a pressure of water is acting against them. Small gates are always made to slide up and down in a groove in the manner of a sluice; some very considerable rivers are furnished with a number of such small draw-gates, which open a great extent of water, when drawn up. In the most extensive works it is necessary to make use of a different kind of gate, which can be opened or shut with greater ease than a number of shuttles, and which will lay open a more extensive passage; for in violent floods it is not uncommon for large trees, bushes, hay ricks, thatched roofs of low buildings, &c. to be brought away by the torrent; and if the flood-gates have any obstruction, these matters accumulate before the passage, and, when the flood lasts long, frequently choak up the gate, and the water overflows its banks. To avoid such accidents is the study of the engineer in constructing works of this kind; the late Mr. Smeaton designed several flood-gates, in which the pressure of the water was balanced, so that the gate at any time could be opened or shut with ease, even while the pressure of the water was acting against it on one side only. *Figures 5 and 6 of Plate XV. Miscellany*, is a plan, and *fig. 2.* an elevation of this contrivance; A A B B represents a channel made through the weir, or, if more convenient to suit the local circumstances, it is made by the side of the river, leading from above the weir to below it: this channel must be substantially built in masonry to resist the violent action of the water rushing through it when the gate is opened; in some convenient part of this passage a stout beam C is placed across the bottom, and another, D, across the top, both firmly bedded in masonry; these support the gudgeons of the vertical axis E of the gate F F. When this gate is turned so as to present its edge to the current, the water has free passage by it, and on the other hand, when it is placed perpendicularly across the channel, the whole of the water is detained: the axis of the gate is placed so as to pass very nearly through the centre of pressure of the superficies exposed to the action of the water; and as the pressure of the surfaces on each side of the

axis act to turn the gate in contrary directions, they balance each other, and the gate may be turned with scarcely any other resistance than the friction of its gudgeons. The gate must necessarily be framed exceedingly strong to bear the great weight of the water acting against it, without yielding. G, H, are two ground-cills firmly bolted down upon the floor of the conduit and the piles which are beneath it; one of the arms of each of these cills support the gate when shut, and the other arms sustain it when open, as is clearly shewn by the figure; these must be very firmly fixed to avoid any danger of the gate removing them; one of the upright sides of the gate is supported by falling into a recess made in the masonry of the conduit, and to keep the other side of the gate up to its cill, a lever, called a vallet, which is in the form of a triangle I K, and moves upon a vertical axis placed in a recess in the masonry so as to be out of the way of the gate's motion, when placed in the position at *fig. 5*, leaving the gate at liberty to open; in the other position it acts as a lever to close the gate, being drawn tight by tackle, and afterwards lashed by a small line to the beam D. The gate is retained shut, but can be opened instantaneously by cutting the line; and as the gate is made rather larger on the side of the axis where the vallet is placed, that it may have a tendency to open when released by the preponderating pressure on one side. The gate in question is 15 feet in height, and the same in breadth; when open, it allows two passages of 15 feet by 6 feet 3 inches in width; the gate is to be shut by the application of a capstan and blocks, for which purpose eye-bolts are provided on the proper points of the gates and beam D.

This gate, though very proper for large rivers where a watchman must be in constant attendance to open and shut it when necessary, is not so applicable as a common sluice to a small mill-dam, where, if a sudden flood occurs in the night, the miller must rise to open the gate; and, unless he constantly attends to shut it when the flood subsides, the mill-dam may be emptied and the water lost, which he would wish to reserve for the ensuing day. Great complaints are frequently made in the country of lands being overflowed in the night when the miller is not in the way to open his flood-gate; to remedy this a self-acting flood-gate would be desirable, and we beg leave to suggest the following. Let A A, *fig. 7*, be a gate similar to the one before mentioned, but of smaller dimensions, and poised upon a horizontal axis passing rather above the centre of pressure of the gate, so as to give it a tendency to shut close: *aa* is a lever fixed perpendicular to the gate, and connected by an iron rod with a cask *b* floating upon the surface of the water, when it rises to the line B D, which is assumed as a level of the weir or mill-dam B C E F, in which the flood-gate is placed; by this arrangement it will be seen, that when the water rises above the dam, it floats the cask, opens the gate, and allowing the water to escape until its surface subsides at the proper level B D; the cask now acts by its weight, when unsupported by the water, to close the gate and prevent leakage; the gate should be fitted into a frame of timber H K, which is set in the masonry of the dam, the upper beam H of the frame being just level with the crown of the dam, so that the water runs over the top of the gate, at the same time that it passes through it; to prevent the current disturbing the cask it is connected by a small rod *c* at each end to the upper beam H of the frame, and jointed in such a manner as to admit of motion in a vertical direction.

This flood-gate would be very useful in mill-dams of small dimension, which are therefore liable to be suddenly overflowed, for being self-acting, it requires no attendance.

and from its simplicity is not very liable to be deranged, as before mentioned; for large rivers the principal object is, to open a great extent of water-way, which will admit the passage of large bodies brought down by the stream; Mr. Smeaton's gate above mentioned, as the axis is always in the channel, would be liable to be choaked by trees, &c.; for this reason large sluices or shuttles are very generally adopted, though the great power and expensive machinery required to raise such gates are an objection.

A flood-gate lately erected by Mr. Bramah is the most perfect in this respect of any that we have met with; it is raised (on the hydrostatic principle which he has so successfully applied to many other useful purposes) with such facility, that a passage 19 feet wide, and 10 feet high, can be opened by one man in 15 minutes, and this when the pressure of 10 feet of water is acting on one side only. *Fig. 8* is an elevation of this gate, and *fig. 9*, an horizontal section; A, A, represent two large beams which are partly received into the masonry of the conduit; the lower ends are framed into a strong ground-cill B, and the upper ends connected by a framing; this forms a frame in which the gate rises and falls: it is guided in its motion by two iron plates *a, a*, bolted to the sides of the gate, forming a groove, as shewn in the plan. Two square pieces of cast iron, denoted by *b, b*, and the dark shading in the plan, are bolted against the inside surfaces of the beams A, A, and received into the grooves of the gate, to confine it to move in a vertical direction: these pieces of iron have cylindrical chambers through them, as shewn by the small white circles in the plan, to admit two polished iron cylinders *d, d*, attached to the end of the upper rail D D of the ornamental framing on the top of the gate; a close fitting is made round the cylinders *d, d*, by leathers confined with screws to press against them at the top of the iron barrels, so that no fluid can pass out of the chamber in the barrels *b, b*; *e, e*, in the plan, are two small pipes communicating with the chambers at the bottom of each barrel, and these pipes are united at *f*, proceeding to a pump, by which water is injected into the two chambers together; and as this fluid is incompressible, it follows that the cylinders *d, d*, must be forced out of their respective chambers raising up the gate. As the area of the pump is much less than that of the cylinders, and as it supplies two of them, it follows that the motion of the piston of the pump will inject such a quantity of water as, when distributed into the two chambers, produces a very small protrusion of the cylinders; it is on this principle of the differences of the two motions that the power is gained: the area of the pump in the present instance is .7854 of a square inch, and the cylinders about 7.07 square inches, or nine times as much; by this means a power is gained in the two cylinders equal to 18 times the force exerted upon the piston of the pump, which being moved by a lever multiplying the power ten times, the power of a man applied to the pump is increased 180 times; so that a weight of 100 lbs. applied to the lever, will raise 18,000 lbs. on the piston rods.

The pump may be placed at any convenient distance from the gate, a small copper tube only half an inch diameter conducting the water into the cylinders in many situations this will be extremely convenient, as it obviates the necessity of an expensive scaffold or framing over the gate, which is indispensable in other sluices to support the labourers and the machinery for drawing up the gate; the pump is explained by *figs. 10*, and *11*, on a much larger scale than the other parts; *b* is a cistern containing water, and the pump-barrel fixed perpendicular in it; the plunger or piston *g* is solid, and leather packed round it in a manner something

When they are dowelled, they may be nailed on one or both edges, though one edge only is necessary; and in the best dowelled work there are no brads or nails seen whatever, the outer edge being fastened by driving the nail obliquely through the wood, without piercing the upper surface; so that the floor, when planed off, appears without blemish.

In laying boarded floors, the boards are sometimes laid one after the other; or otherwise one is first laid down, then the fourth, leaving an interval somewhat less than the breadth of the second and third together. The intermediate boards are next laid in their places, with an edge of the one upon the edge of the first board, and an edge of the third upon the inner edge of the fourth, and the two middle edges together, which will form a ridge; to level which, two or more workmen jump upon it, till they have made the under surface coincident with the joists, then they are nailed down in their places. The operation is called *folding floors*, and the boards are said to be *falded*. This mode is only taken when the boards are not sufficiently seasoned; or suspected to be so. In order to make close work, it is obvious that the two edges forming the joint of the second and third boards must make angles, with the faces, together less than two right angles, or each one of each board less than a right angle. The seventh board is fixed as the fourth, and the fifth and sixth inserted as the second and third, and so on till completed. In this kind of flooring the headings are generally square or splayed.

When floors are dowelled, the regulating line for the centre of the dowels should be drawn from the lower side, which, as has been observed, ought to be straightened on purpose. The distances to which the dowels are set, are from six to eight inches, generally one over each joist, and one over each inter-joist.

When it is necessary to have a heading joint in the length of the floor, it should always be upon a joist; one heading joint should never meet another. In dowelled floors the heading joints are always plowed and tongued.

In common floors the boards are adzed on the lower side, in order to bring them to a thickness between rebated edges. In doing this, great care should be taken so as not to make them too thin, which is frequently the case; they must then be raised with chips, which is a very unstable resistance to a pressure upon the floor. The manner of measuring floors is by squares of ten feet on each side, so that taking the length and breadth, and multiplying them together, and cutting off two decimals, the content of a floor in squares will be given. Thus 18 by 16 gives 288 of 2 squares and 88 decimal parts.

Floors, *Earthen*, are commonly made of loam, and sometimes, especially to make malt on, of lime, and brook-sand, and gun-dust, or anvil-dust from the forge; the whole being well wrought up and blended together with blood. The fittings of lime stone have also been found highly useful when formed into floors in this way.

Ox-blood and fine clay, tempered together, fir Hugh Plat says, make the finest floor in the world. The principal object in constructing floors of this nature is that of blending and incorporating the different substances in a full and perfect manner for some time before they are laid; and when that is done they should be repeatedly beaten down and rendered perfectly smooth and even.

The manner of making earthen floors for plain country habitations is as follows. Take two-thirds of lime, and one of coal ashes well sifted, with a small quantity of loam clay; mix the whole together, and temper it well with water, making it up into a heap: let it lie a week or ten days, and then temper it over again. After this,

heap it up for three or four days, and repeat the tempering very high, till it become smooth, yielding, tough, and gluey. The ground being then levelled, lay the floor therewith about $2\frac{1}{2}$ or 3 inches thick, making it smooth with a trowel: the hotter the season is the better; and when it is thoroughly dried, it will make the best floor for houses, especially malt-houses.

If any one would have their floors look better, let them take lime made of rag-stones, well tempered with whites of eggs, covering the floor about half an inch thick with it, before the under flooring is too dry. If this be well done, and thoroughly dried, it will look, when rubbed with a little oil, as transparent as metal or glass. In elegant houses, floors of this nature are made of stucco or of plaster of Paris beaten and sifted, and mixed with other ingredients. Well wrought coarse plaster likewise makes excellent safe upper-floors, for cottages, out-houses, &c. when neatly spread out upon good strong laths or reed. See *PLASTER-Floor*.

Floor of a ship, strictly taken, is only so much of her bottom which she rests on, when aground.

Such ships as have long, and withal broad floors, lie on the ground with most security, and are not apt to heel, or tilt on one side; whereas others, which are narrow in the floor, or, in the sea phrase, *cranked by the ground*, cannot be grounded without danger of being over-turned.

Floor timbers, in a *Ship*, are those parts of a ship's timbers which are placed immediately across the keel, and upon which the bottom of the ship is framed; to these the upper parts of the timbers are united, being only a continuation of floor-timbers upwards.

Floor, in *Mining*, or sole, thill, or pound stone, signifies the bottom of the work in a mine, or in coal-mining, the stratum immediately under the coal-seam; which if soft, the upper part of it for six or eight inches in height generally is "holed in," as the colliers call it, that is, the same is picked out in order to undermine or loosen the coal, but if the floor be hard, as clunch is, the holeing or picking is then made in the bottom or some inferior bed of the coal itself, in order to under-go or give room for wedging down the blocks or webs of coal. In examining and comparing the sinkings of the numerous coal-pits in Derbyshire and Nottinghamshire, Mr. Farey lately discovered, what seems likely to prove a general and important geological fact, viz. that the floor of every coal is a fire-clay, more or less thick, more or less perfect in its infusible property, and more or less indurated; sometimes being in a soft or ductile state, when it is called *loam*, *spavin*, *fire-clay*, *pipe-clay*, (if white,) *potter's-clay*, *brick-clay*, &c. at others, in an indurated or almost stony state, but which it quickly loses and falls to clay, on exposure to the atmosphere, in which case it is called *clunch*, which is the name that the floor of coal most generally bears. This new fact appears to throw a great degree of light on the new theory of the formation of coal, near the end of our article *COLLIERY*, by rendering it probable that the growth of the subaqueous beds of vegetables there spoken of were produced by this peculiar substance as their soil or pabulum.

Floor, a superficial measure of 400 square feet or docking, is a square whose side is 20 feet, and occurs in the facing of the sea-banks, and in other works on the fens of Cambridgeshire and Norfolk, &c.

Floor, a solid measure of 400 cubic feet, or a superficial floor, one foot thick, used in measuring the pits dug to obtain earth for forming the banks against the tide or rivers in the fens on the eastern coast (Smeaton's Reports, vol. i. p. 330.)

Fluor

FLUOR, in *Physics*, &c. denotes a fluid; or, more properly, the state of a body, which was before hard and solid, but is now reduced, by fusion of fire, into a state of fluidity.

Gold and silver will remain a long time in fluor, maintained by the intense heat, without losing any thing of their weight. See GOLD, FIXITY, &c.

The word fluor is applied to signify the habitual fluidity of any substance, or that property by which a substance cannot be rendered solid, and is employed as an epithet to distinguish such substances from others of the same kind, but which are habitually solid, or which may be rendered solid.

FLUOR, in *Mineralogy*, a species of the calcareous genus, being a combination of lime and fluoric acid, and known by the chemical appellation of *fluat of lime*. The more familiar names under which it passes in most countries are *fluas* and *fluor*, denoting the use to which it is frequently applied as a flux of various ores. Beside these, there are a variety of other names that have originated in the similarity of its colours, (particularly those of the fluor-spar,) to the beautiful tints of several of the stones called precious; such are *false emerald*, *hyacinth*, *topazes*, *beryl*, *chrysolite*, &c. Indeed there is no mineral that may equal fluor in the varied beauty of its hues; the suite of its colours is almost sufficiently comprehensive to be formed into a chromatic scale. It is reserved for nicer chemical observation to discover the nature of this variously modified colouring principle, which is more fugacious in fluor than in most other minerals, but probably always corresponding with the nature of the metallic substances that accompany fluor in the bowels of the earth.

Fluor has been divided by Werner into three sub-species, namely, *earthy*, *compact*, and *spathose fluor*. The first, also known by the name of the phosphorescent *earth of Marmaross*, was classed with the fluates of lime on the authority of Pelletier; but the late analytical experiments of Klaproth, who found 32 parts of phosphoric to two of fluoric acid, shew the necessity of restoring it to the phosphates of limes, to which it was first referred! Mr. Jamelson appears to have had his doubts respecting this substance; he does not describe it as a sub-species of fluor, nor does he enumerate it among the phosphates of lime. See PHOSPHORITE.

1. *Compact fluor*. This is rather better understood; but it appears that mineralogists are very apt to confound the terms "compact" and "massive" also in speaking of fluor; whence massive fluor spar has been described as Werner's compact fluor. This latter occurs but rarely, having hitherto been found only at Stollberg and Strassberg in the Hartz, and at Yxjö and Norberg in Sweden, to which habitats we may perhaps add Schlackenwalde and Kriman in the Saatz circle of Bohemia, and Schwarzkogang in Salzburg. The following external characters appear the most important.

Its colour is generally light greyish-green, passing sometimes into greenish-white, sometimes into blueish-grey, approaching to verdigris green, and it is also found reddish. Not seldom several of these shades are mixed in spots in one and the same fragment, now and then with the addition of accidental yellowish and brownish spots.

It occurs massive only. Fracture more or less even, approaching sometimes to flat conchoidal, sometimes to splintery, even to foliated. The fragments are indeterminately angular with pretty sharp edges, and more or less translucent in the same piece.

It is feebly glimmering, almost dull. Half-hard, scarcely scratched by fluor spar, brittle, easily frangible. Its specific gravity, if Kirwan's compact fluor be the same as the one here described, is 3.120 to 3.165.

This sub-species, to a superficial observer, appears sometimes like horn-stone, sometimes like compact lime-stone; but the above external characters (to which may be added the physical one of its shewing a weak phosphorescence when laid on ignited coal) keep it sufficiently distinct. Its geognostic situation at Stollberg is in a vein, in greywacke; it is found with fluor spar (its constant companion), some copper pyrites and barytes. At Kriman in Bohemia it was found by Dr. Reuss in gneiss, in which it is sometimes seen as thin laminæ between the layers of quartz and feldspar.

It is, together with fluor spar, made use of as a flux.

2. *The sparry fluor*, or *fluor spar*, which, besides the above-mentioned general names, is also known under those of *cubic fluor*, *glass fluor*, *phosphorescent spar*, *spath vitreux*, *spath fusible*, &c.

Its principal colours are, 1. *White*, such as greyish, greenish, yellowish, and reddish-white, passing into 2. *Red*, particularly rose red of various intensity, carmine. 3. *Grey*, greenish, yellowish, smoke, and pearl-grey. 4. *Blue*, lavender, azure, smalt, sky-blue, Prussian and violet-blue, the two latter appearing sometimes nearly black. 5. *Green*, verdigris, celadon, mountain, emerald, grass-apple, leek, pistachio, and olive green. 6. *Yellow*, wine, wax, honey yellow. 7. *Brown*, yellowish, and clove-brown. All these colours will frequently pass into each other, and even those least related to each other are sometimes seen together in the same specimens in spots and flakes, and in stripes that often appear like some kinds of alabaster, whence Rome de l'Isle called a variety of fluor, *alabaître vitreux*. The colouring matter of some of them is very fugacious, especially that of the sky-blue variety, which is often seen to fade merely by being exposed to the atmospheric air. Of the above colours, the white and violet blue are the more common.

Fluor spar is found massive and disseminated, and most commonly crystallized, but it has not been observed, except in one instance to be mentioned hereafter, in those imitative shapes, (such as dentiform, branched, stalactitic,

&c.) in which the carbonates and sulphates of lime, and other crystallizable earthy substances so frequently occur.

Its primitive form is the octaedron. As to the determination of the integrant molecule some difficulty has arisen. The octaedron, we know, cannot be sub-divided into solids of the same form; the last term of mechanical division we arrive at is that into other octaedrons accompanied by tetraedrons; six of the former and eight of the latter being disposed in such a manner as to form in all directions acute rhomboids. If we imagine either all the octaedral or all the tetraedral particles removed, those of the same kind that remain will still be in exact connection by means of their edges. Of the latter circumstance Häüy has ingeniously availed himself to reconcile this resolution of the octaedral crystal into two kinds of solids, with that principle according to which all the integrant molecules of a crystal must be necessarily similar. He supposes that, could we cast a look into the primary construction of the octaedral crystal, and sub-divide it to the utmost limits, we should find the whole substance pervaded either by tetraedral or octaedral vacuities; if the former, the whole would be composed of octaedral elementary particles, if the latter, the tetraedron would exclusively constitute the integrant molecule. Now as, according to Häüy's doctrine, this molecule is constantly either the parallelopiped, or the triangular prism, or the tetraedron, analogy has in this case decided in favour of the tetraedron, which is now considered as the integrant molecule of fluor, instead of the octaedron. It was Werner who first observed the tetraedral and octaedral fragments which result (according to his terminology) from the fourfold cleavage presented by the foliated fracture of fluor.

The principal forms of the crystals of fluor-spar, with their modifications, considered, not according to their origin, but to the manner in which they present themselves to the eye, are the following:

1. The perfect cube (*chaux fluatée cubique*, Häüy.) It is sometimes elongated; passing from the cubic form into that of a rectangular four-sided prism, generally with two of its lateral planes narrower. We have seen specimens of the latter variety from Cumberland; it is also found at Schemnitz and Nertschinsk.

2. Cube with all the edges truncated (*chaux fluatée cubo-dodécædre*, Häüy.)

3. The preceding with planes of truncation so much increased that the rhomboidal or garnet-dodécædre is formed (*chaux fluatée dodécædre*, Häüy.)

4. Cube with all its edges bevelled (*chaux fluatée bordée*, Häüy.)

5. The preceding, with bevilling edges so much enlarged as to convert each plane of the cube into four triangular planes (*chaux fluatée hexatétraèdre*, Häüy.) What has been described as perfect cube with convex planes, we suppose to be this modification indistinctly formed.

6. Cube with all its solid angles flatly acuminated by three planes, placed on the lateral planes of the cube.

7. Cube having its angles acuminated by six planes, placed on the lateral planes. We do not know where the preceding and this variety occur; Emmerling informs us, that in the latter the six acuminating planes sometimes completely engross the planes of the cube.

8. The cube truncated at all its solid angles (*chaux fluatée subo-octædre*, Häüy.) If the triangular truncating

planes do not meet, the planes of the cubes are octagons; if they meet exactly, those planes are squares; if all the truncating planes encroach on each other these become hexagons, while the planes of the cubes remain squares; when they encrease still more the

9. *Octaedron*, with six truncated angles, is formed; in which the truncating planes are the six planes of the cube; in the same manner as the truncations at the eight angles of the cube N° 8. are the eight planes of the octaedron. When the truncating planes of the modification N° 8. enlarge so much as to cause the faces of the cube entirely to disappear,

10. The perfect octaedron, or double four-sided pyramid, is formed (*chaux fluatée primitive*, Häüy.)

11. Octaedron with truncated edges (*chaux fluatée emarginée*, Häüy.)

12. Octaedron with both angles and edges truncated.

13. The elongated octaedron with four broader and four narrower planes, terminating in a ridge.

No. 1. is by far the most common of all the modifications of crystallized fluor spar. No. 3. is very rarely met with; it was found by M. Subrin between Breuil and Charecey on the way to Chalons. Of No. 4. the most interesting varieties occur in Cornwall. From the geometrical figure in plate 73, of that useful work "British Mineralogy," it appears, that Häüy's *chaux fl. bordée* occurs in Cornwall, with the eight angles truncated, parallel to the octaedron, by which a crystal of 38 faces is formed. Of No. 10, the perfect octaedron, the most beautiful variety is the rose-coloured one, found in the neighbourhood of Mont-Blanc. It also occurs in beautiful crystals in England, on Mount St. Gothard &c. and Mr. Sowerby is, we suppose, the first who has noticed the small violet variety of this modification found in Aberdeenshire.

To the above may perhaps in future be added the following unusual modifications. 1. The *tetraedron* with faintly truncated edges, mentioned by Mr. Mohs as existing in the collection of Mr. Vonder Null: the truncating planes are stated to correspond to those of the cube. 2. The rhomboid (one of the forms which fragments of fluor-spar frequently exhibit, and which may be considered as an octaedron, with two tetraedrons applied to two of its opposite planes) is said to have been found as crystal. The third, mentioned by Emmerling, is the double eight-sided pyramid, acuminated at both extremities by three planes placed on the alternate lateral edges. It is said to have been found in Saxony, and is in the collection of Count Wrba at Vienna.

The crystals of fluor spar are of various size: the perfect cubic is seen from five inches square to extremely minute, and scarcely distinguishable. They are found distinct and aggregated in various directions; sometimes globularly aggregated. Their surface is generally smooth and splendid; but sometimes perfectly dull. They are not seldom covered by an opaque crust of various colours, particularly blueish-green; often they are drusy, and sometimes ornamented with a beautiful golden and pavonine tarnish: of which latter we have a fine specimen before us. Internal lustre splendid, sometimes simply shining, according to the various degrees of perfection of the foliated fracture; it is vitreous, rather inclining to pearly; in some varieties even an adamantine lustre has been observed.

Fracture more or less perfectly foliated, almost always straight, seldom curved-foliated, sometimes approaching to vitreous; it presents a four-fold equiangular cleavage.

The form of the fragments has been mentioned in speaking of the integrant molecules. The massive is generally seen in granular distinct concretions of various bigness; and sometimes it appears in columnar concretions, and radiated, intersected by curved lamellar distinct concretions.

Degree of transparency according to the differences in the colour and fracture; some varieties, particularly the white or colourless, perfectly transparent; others entirely opaque; most commonly it is semi-transparent.

Its hardness is greater than that of calcareous spar; but it is scratched by iron; it is brittle, easily frangible, and not very heavy; its specific gravity is,

3.092 (from Stollberg)	} Gellert.
3.148 (from Freiberg)	
3.156 to 3.184. Muschenbroeck.	
3.175 (the green var.) Blumenbach.	
3.200 to 3.700. Gerhard.	

Other physical characters are its phosphorescence when laid on ignited coal; the sky and violet-blue and green varieties have been observed to emit the most vivid phosphoric light. The variety from Siberia, called chlorophane, when put on ignited coal, does not decrepitate, but emits a beautiful emerald green light, which has procured it its name. A slight phosphorescence is likewise observed when two fragments are rubbed against each other in the dark.

As chemical characters of fluor-spar, we have to mention its decrepitation before the blow-pipe, (which, however, is not the case with the Siberian chlorophane,) and subsequent loss of colour, and its melting, (particularly with addition of borax or phosphoric acid,) into a greyish-white enamel; as also its emitting suffocating white vapours (fluoric acid) when acted upon by sulphuric acid.

The constituent part of fluor-spar, according to Scheele, the celebrated discoverer of a peculiar acid in this mineral, were stated to be,

Lime	57
Fluoric acid	16
Water	27

After him, Wenzel, Richter, and but lately Klaproth, have analysed this substance, and obtained the following results.

Fluoric acid	32½	100	Wenzel, 1783
Calcar. earth	56½		
Iron and alum earth	10½		
Fluoric acid	35	100	Richter, 1785
Calcar. earth	65		
Calcar. earth	67.75	100	Klaproth, 1807.
Fluoric acid	32.25		

With regard to the *geognostic situation* of fluor spar much is left to future observation. We know, however, that it does not only occur in veins, but likewise as beds, principally in mountains of older formation. In Derbyshire it appears to form large irregular depositions in Stetz lime-stone, and also in Thuringia and at Zinnwald in Bohemia it occurs in beds. More frequently it is met with in veins of different relative ages, accompanied with several important metallic formations. The oldest, consisting principally of tin stone,

occurs at Zinnwald, and in other parts of the Bohemian and Saxon Ertzgebirge: and a vein formation, equally old, is found in Switzerland, where the veins consist of fluor spar, feldspar, rock crystal, &c. The second in antiquity appears to be that which, accompanied with lead and silver ores, and sometimes with barytes, forms the substance of veins at Freiberg and other parts of the Saxon Erzgebirge, and also partly in Derbyshire. A third vein formation, found in the lower parts of the Hartz, consists chiefly of fluor spar with copper and iron pyrites, galena, spathose iron, &c. The different ages of the venigenous fluor spar have first been examined into by Werner. We should also mention here that the variety of fluor called chlorophane is found in a granitic rock in Siberia; and Andrada speaks of a variety he saw in Sweden (in the district of Norberg) mixed in large masses with mica slate.

A list of localities of fluor spar may be found in all books on mineralogy; indeed, it is met with in most parts of Europe, though in some it is found in no considerable quantity. England and Saxony are the principal native places of this interesting mineral substance. In Scotland it is very scarce; the only localities known to Mr. Jameson are Aberdeenshire and the Shetland islands. We know of no specimens from any part of America or Africa; in the northern parts of Asia, Patrin found it in small quantities in two mines, viz. in the silver mine of Zmeof, in the Altaic mountains, where it occurs mixed with the other vein-materials; and in a lead mine in Dauria, near the river Amur, where, if Patrin's observation be correct, it coats the small cavities of the vein stone, in the shape of a thick *botroidal* crust.

The uses to which fluor spar is applied, though not manifold, are not unimportant. The coarser kinds are used as fluxes to metallic ores, particularly copper, iron, and silver. Chemists obtain fluoric acid from it. The use made of it in this country, (particularly of the variety called blue jack by the Derbyshire miners,) for ornamental vases, columns, &c. is generally known. Mr. Mawe, in his "Mineralogy of Derbyshire," has given an account of the mode of working it. Several attempts have been made in France to manufacture the fluor spar of Auvergne into similar articles of ornament; but it appears as if the nature of its fracture renders it less fit for the lathe.

Fluor spar is seldom seen to constitute the substance of organic remains. We find instances of this conversion mentioned in Mr. Martin's "Outlines;" the remains are chiefly those of *entrochite*. Also Dr. Kidd, in his "Outlines, &c." describes a bivalve shell in the Oxford collection, converted into fluor spar with imperfect crystals of nearly colourless fluor in the interior.

We should not omit mentioning in this place those corroded cubic crystals of fluor spar, of a yellowish-grey colour, found near the surface of the earth in some parts of Derbyshire: their texture is more or less porous throughout. Haüy, who calls this variety *chaux fluatée aluminifère*, thinks that the ferruginous clay which it is said to contain has the same relation to the fluor spar which the quartz grains have to the carbonate of lime in the crystallized sandstone of Fontainebleau. But this analogy does not appear to be founded in reality. (See SANDSTONE.) Dr. Kidd conjectures that the corroded appearance of these crystals may have been produced by some form of zinc.

Fluor spar sometimes exhibits traces of decomposition. The singular variety from Beeralston, Devonshire, in octahedral crystals of a pale celadon green colour, and cased, as it were, in one another, is encrusted with a white earthy substance, which, if we may judge from the gradual

transition into the perfect substance observable in a specimen before us, can only be the result of a disintegration of the constituent parts. Mr. Sowerby has given a good figure of this variety. It is probable that much of the substance described as earthy fluor is nothing but fluor in a decomposed state.

FLUOR Allus, in *Medicine*, a colourless discharge from the female vagina, popularly termed *the whites*, and by the nosologists *leucorrhæa*, an appellation of the same signification, derived from the Greek. See *LEUCORRHÆA*.

FLUORIC ACID, in *Chemistry*. This acid was discovered by Scheele more than thirty years ago, and the subject soon after excited the diligent attention of Dr. Priestley, whose experiments and observations are detailed at large in the second volume of his experiments methodized, p. 339, 367. For many years it was supposed to exist in the fluor spar only, but later processes have shewn that it is a constituent of some of the topazes, and of the wavellite, a newly discovered fossil. It has also been found in the animal kingdom, viz. in the enamel of the petrified teeth of an elephant: also in the enamel of the human teeth, and in ivory.

We have seen that the constituent parts of fluor spar, independently of the water in combination, are fluoric acid and lime. To obtain this acid we must put one part by weight of the spar coarsely pulverized into a leaden retort, and pour over it three parts of concentrated sulphuric acid. An effervescence is immediately excited; the sulphuric acid exerting a stronger attraction for the lime of the spar, unites with it, and the fluoric acid goes off in the form of gas, which may be collected in receivers over mercury. If water had been previously introduced into the receiver, the gas would have been absorbed, and the acid would, in that case, be exhibited in the liquid state. Hence fluoric acid can subsist in the liquid form, and likewise under that of gas, which gas has the common properties of the atmospheric air, being elastic and invisible. But it is somewhat heavier than common air; it extinguishes combustion, and is utterly incapable of supporting animal life. Exposed to the atmosphere it combines very greedily with its moisture, and appears in the form of vapour or white fumes. It has a penetrating pungent smell; reddens vegetable blues, and corrodes the skin. If a lighted candle be introduced into it, the flame becomes green, and then is extinguished. The most remarkable property of the fluoric acid gas is that of corroding glass in consequence of its strong affinity for silica. This property has rendered it extremely useful in etching or engraving on glass vessels, which operation is performed by a very simple and easy process: the glass is covered with wax, or a strong solution of isinglass, the figures are then traced with a common graver, or steel point, and then the vessel is exposed to the action of the fluoric acid in a state of gas; those parts that are exposed are soon corroded, and the impression is more or less deep, according to the time employed. This art, though adopted as new at the time of Scheele's and Priestley's discoveries, was, according to the account given by Beckmann in the second volume of his *History of Inventions*, known and practised a century before.

Light and caloric have no effect on fluoric acid; its properties are not the least altered by being passed through a red-hot porcelain tube. It will not unite with oxygen, which is the great difference that exists between this and the muriatic acid; nor has it any action on azote, hydrogen, carbon, phosphorus, or sulphur. By these, or by some of them, almost all the other acids have been decomposed, and their constituents detected, and hence its base was, till very

lately, wholly unknown; and it was, from analogy only, that chemists assumed that it must contain oxygen in combination with an unknown base. Mr. Davy has, however, thrown some light on this subject, by subjecting the fluoric acid-gas to the action of potassium, one of his newly discovered metals. In this gas potassium, when heated, burns, and there is a great absorption of the gas. Either the whole, or part of the acid, according to the quantity of the potassium used, is destroyed or absorbed, and the residual elastic fluid is found to be hydrogen, which is in less proportion as the fluoric acid gas has been more perfectly freed from water. After the combustion, a chocolate coloured mass remains at the bottom of the retort, and also a sublimate, partly chocolate coloured, and partly yellow, is found about the sides, and at the top of the retort. This substance, when examined by a magnifier, appeared to consist of different kinds of matter; and when thrown into water it effervesced very violently, and the gas evolved was inflammable. When heated in contact with air it burnt slowly, lost its brown colour, and became a white saline substance.

The water which had acted on this substance was examined, the solid particles separated by a filtre, and the fluid was found to contain fluates of pot-ash, and pot-ash. The solid residuum was heated in oxygen gas, it burnt before it came to a red heat, the brown colour was changed to white; oxygen was absorbed, and acid matter was produced. The inflammable substance thus produced from the action of potassium on the fluoric acid is supposed to be the base of the acid. Perhaps the decomposition of the fluoric acid by potassium is analogous to that of the sulphuric and phosphoric acids; in which the pure bases are not evolved, nor even the bases in their common form, but new compounds formed of the base with potassium, with a smaller proportion of oxygen. This subject has engaged also the attention of the French chemists, M. M. Gay Lussac and Thenard, who employed the agency of potassium, and the results of their investigation were very similar to those of Mr. Davy. From which they infer that since little or no hydrogen gas is evolved in the combustion of potassium, the effect cannot be ascribed to the agency of water. The acid must therefore be decomposed, or it must combine undecomposed with the metallic base, which is not even oxydated. It is probable, therefore, that the acid is decomposed, and the product is a combination of the fluoric base with pot-ash, analogous in constitution to a phosphuret.

Fluoric acid combines with alkalis and earths, and the salts so formed are named fluates. They are generally deliquescent, and can be crystallized with difficulty. They are decomposed by the sulphuric or muriatic acid, which, as we have seen, disengages the fluoric. The alkaline fluates are decomposed also by lime, as is evident by the following

Table of Affinities.

Lime,
Barytes,
Strontites,
Magnesia,
Pot-ash,
Soda,
Ammonia,
Glucina,
Alumina,
Zircon,
Silica.

The saturating power of this acid exceeds that of all the

others, a given quantity of it saturating a larger quantity of any base. On this account, it is regarded as the most powerful of the acids, and its less energetic action must be ascribed partly to the weak state of concentration in which it can be obtained, and partly to its not affording oxygen in a direct way.

There are eight fluates known, *viz.* of pot-ash, soda, ammonia, lime, barytes, magnesia, alumine, and silica. Some of these we shall briefly notice. The fluat of *pot-ash* is obtained by fusing, in a platina crucible, a mixture of fluor spar, and carbonate of pot-ash. The mass, digested in water, yields a solution, which, filtered and evaporated, leaves a fluat of pot-ash. It does not crystallize, but forms a gelatinous mass with scarcely any taste, that attracts moisture from the air. It readily dissolves in water. F. of *soda* is formed like the last; if the solution is evaporated till a pellicle rises on its surface, it yields on cooling small cubical crystals of fluat of soda. These are bitter and astringent; they do not deliquesce in the air, and are but little soluble in water. They decrepitate and melt into a transparent globe when exposed to the action of the blow-pipe. F. of ammonia is obtained by the application of heat to a mixture of sulphate of ammonia and fluor spar. The fluat sublimes; but if it is prepared by saturating the acid with ammonia, the solution, by evaporation, yields small crystals of fluat of ammonia. F. of lime, is the fluor spar on which we have already treated, as it is found in nature; this salt may be artificially prepared by adding fluat of ammonia to nitrate of lime; the fluat of lime falls to the bottom, and

when properly treated is very pure. It is insoluble in water, phosphorescent when laid on a hot iron, it is insipid, unalterable by exposure to the air, and at a heat equal to 51° of Wedgwood, it melts into a colourless transparent glass. Fluoric acid obtained in glass vessels always contains a portion of silica; if this solution be allowed to remain a considerable time in a vessel not quite closed, it deposits small brilliant transparent crystals, which have been ascertained to be the fluat of silica. This salt is soluble in alkalies, and gives out fluoric acid by mere heat, or by the action of any of the strong mineral acids. Felspar, and all minerals that contain silica, are probably acted on without difficulty by the fluoric acid in a state of gas, but those that contain no alkali are less liable to its action. The following table, taken from Dr. Thomson's chemistry, vol. ii. exhibits the results of the experiments and calculations of Richter on the several fluates.

Table of the Composition of the Fluates.

Fluates of	Acid.	Base.
Alumine - -	100	1:3
Magnesia - -	100	1:4
Ammonia - -	100	1:57
Lime - -	100	1:86
Soda - -	100	2:01
Strontian - -	100	3:11
Pot-ash - -	100	3:76
Barytes - -	100	5:20

Flux

FLUX, in *Enamel*, is that glassy body that forms the basis of all enamels, whether transparent, semi-transparent, or opaque. Now as the painting on enamel is performed with vitreous colours, which to speak truly can be nothing more or less than coloured enamels, it must be evident that flux likewise forms a principal part in the composition of enamel colours.

FLUX, *Enameller's*, is a sort of enamel principally used for the upper surfaces of plates intended for enamel painting. It differs from the common enamels, in being of a more mellow and rich quality, whilst its properties facilitate the fusion of those colours which are employed in painting on it. The best kinds having been generally brought from Venice, have acquired the name of *Venetian flux*, and are commonly imported in the form of small beads, hence called *bead-flux*, or short pipes about three-eighths of an inch in diameter, and from three quarters of an inch to an inch in length: the latter is called *pipe-flux*. The fluxed plates, when prepared as described under **ENAMELLING**, have a rich yellow hue, or cream colour; by which they are rendered of particular utility in paintings where much of the naked figure is exposed. The flux must always be laid upon *hard* enamel; as the properties of glass enamel are inimical to effective cohesion, the flux cracking in circles, or flying off in pieces as the plates cool.

In order to give a clear idea of the nature of fluxes, it will not be improper previously to inquire more particularly into the nature of the ingredients, their operations on each other in a state of composition, as well as the power which each exerts in producing a proper effect; since by this means such an initiative knowledge may be obtained, as will enable persons unacquainted with the art to conduct their experiments with more certainty, than they possibly could by any particular recipes, however good they might be.

There are two kinds of substances which enter into the composition of enamel fluxes; the one, the proper matter of the flux, being principally such bodies as are by their nature endued with a strong propensity to run into the vitreous fusion, and be converted into glass, at the same time that they assimilate and change other bodies in combination with them into their own vitreous nature. This kind consists principally of salts, lead, and arsenic. The other kind consists of the correctives of these proper fluxings, which without their admixture would be found to have qualities that would deprave them for enamels or the fluxes for paintings. For all kinds of salts, when vitrified by themselves, or with a small proportion of other bodies, are still liable to be dissolved by aqueous moisture; and flux, made of such ingredients only, would be corroded even by the common air, and turn black and dull on its surface; hence it becomes necessary to add some other bodies as correctives to prevent these bad tendencies, and render the flux more durable. Lead and arsenic, when formed into glass, of which they compose the principal ingredients, are particularly liable to be thus corroded; to prevent which, when using these substances, it is necessary to add considerable proportions of the corrective matter. The truth of these remarks may be readily ascertained by the appearance of the enamel door-plates about this town, in many of which the lead, having been used in too great a proportion as a flux for the black colour, has been so far corroded as to have admitted the air to come in contact with the colouring matter, in which case the whole writing is almost obliterated.

The most common of these corrective bodies of the proper matter of the flux, and which therefore make the second kind of substances of which enamel fluxes are composed, are calcined flints, and Lynn sand, or what is generally known by the name of silver sand, which being perfectly white, and resisting when vitrified the corrosive and

decomposing action of all menstrua, give body and hardness to the fluxes, without any other disadvantage than that of diminishing, in a certain degree, their inclination to vitrify, and on that account rendering them somewhat weaker as fluxes than they would be if used alone.

The most active kind of salt as a general flux is borax, which possesses the greatest power of any simple body hitherto known. Lead, which is the next, vitrifies with a very slight heat, and at the same time assimilates other bodies to its own nature, such as earths, stones, the oxyds of metals, &c. Arsenic is likewise a powerful fluxing substance; but whenever this is used it should be with bodies that have been previously vitrified and ground tolerably fine, otherwise it is apt to sublime and fly off from the composition with which it is mixed, and which of course must render any recipe, where a certain proportion of this is to be used, very liable to error without such precautions. Several kinds of salts possess the next degree of fluxing power, the principal of which is sea salt; but it must be evident from what has been mentioned, that they are not sufficiently strong to form an enamel flux by themselves, yet as they are perfectly colourless when vitrified, which is not the case with lead, they will be found very useful in composition with lead, or when used in place of that substance, assisted by borax, especially where any tinge of yellow would be detrimental to the colouring matter that is to be used with the flux.

Having endeavoured to give the reader an idea of the nature of the substances that are used in the formation of fluxes, we shall next endeavour to explain the method of compounding them before they are fused, and also some observations upon that part of the process.

When the materials are procured, taking care that they are of the best quality, each should be separately levigated either in an agate mortar, or one made of the same kind of glass as the common wine bottles are made of: the pestle in either case should be of flint or agate. The proportions of each substance, having first been thoroughly mixed, the whole must be put into crucibles of a proper size, and placed in an air furnace, or what is more commonly called a wind hole, where the heat should be increased till the matter is perfectly vitrified, which may be known by its becoming clear and transparent. The heat must be sufficiently powerful, yet not too violent, for though a great heat may accelerate the vitrification, yet it at all times hardens the composition, and greatly reduces the fluxing power. The simple method of dipping the end of a tobacco pipe in the flux while in a state of fusion, and examining the small quantity that adheres to it, will enable a person to form an accurate judgment of the whole; for if it appears clear and transparent it may be concluded that the vitrification is complete, but if any cloudy parts appear inclosing opaque specks, it is evident that a longer continuation of heat is necessary. When the quantity is small it becomes very difficult to get the whole out of the pot; the best method perhaps is to hold the edge of the pot with a convenient pair of tongs, and at the same time scrape the matter out with a small piece of iron, the edge of which should be previously made to fit the bottom of the crucible. Whoever would have flux in the greatest degree of purity, must previously prepare the glass of lead to be ready at all times for use, for although lead might be mixed with the other ingredients for common purposes, yet it will be better in all cases to prepare it previously by the following means.

Take of the best minium, or, as it is commonly called, red lead, four pounds; of Lynn sand, or calcined flints, two pounds and a quarter: these two substances should be

thoroughly mixed, and be put into a very sound crucible. One that has had flux or a little flint glass melted in it before would be preferable, for when a new pot is used, the lead is very liable to strain through the pores, and thus occasion an uncertain result, although the quantities should have been ever so nicely adjusted. This is to be vitrified in the same manner as directed for flux, and when perfect will be of a beautiful topaz or transparent gold colour. When the matter is cold, it should be ground in the mortar before described, and then kept perfectly free from dust.

In most large concerns in the glass business sand is greatly preferable to flints, as the trouble of calcining and grinding the latter, where large quantities are wanted, is a serious objection to their use. But in the case of flux, where quality is of more consequence than quantity, flints are certainly preferable.

The method of preparing the flints for use, is to place them in a clear fire, in which they should continue two or three hours; the fire should be then increased till they attain a white heat, at which time they should be taken very quickly from the fire and plunged into cold water, which will cause them to crack and flaw in innumerable parts; they must then be broken into pieces, and if they are of an uniform whiteness throughout, they may be considered as fit for grinding; but if any black and discoloured places appear, they must be again submitted to the fire, and the immersion in water repeated; the calcination being then completed, they must be broken as small as possible with a steel-faced hammer, and ground very fine in the glass or agate mortar.

A very important advantage attending this preparation of the glass of lead, is the ease with which a very perfect vitrification of the sand or flints is effected without the aid of intense heat; at the same time the mixture is rendered more capable of assimilating with a larger proportion of salts, which will in all cases add greatly to the softness of the flux.

Very little hope is entertained that any more of the Venetian hard enamel or flux for grounds will be imported into this country, as we are assured that Bertolini, the celebrated maker of those substances, perished in the hands of the French at Naples, on account of his political opinions. We feel much pleasure in being able to state, however, that Mr. Griffiths of Broad Court, Long Acre, London, after many years spent in making enamel colours, has succeeded in making flux for grounds equal to any of the Venetian, which he has constantly for sale. He has likewise, within the last three years, brought to perfection a beautiful white, hard enamel, which is so nearly equal to the Venetian, that the one might be mistaken for the other, the colour and fracture being so much alike.

The first recipe for the formation of a flux, and which we shall call N^o 1, is the white glass enamel, which, containing a large proportion of arsenic in a semi-vitrified state, requires to be broken into small pieces, and fused till the matter becomes quite clear and transparent; the arsenic will by this means be completely vitrified, and convert the glass into a soft and useful flux, fit to be mixed with most of the earths that may be used as colours, and likewise with the oxyds of all the metals, gold and silver excepted; for it must be remembered, that lead and arsenic are both apt to injure the beauty of the colours that are produced by gold and silver: therefore, whenever these are used, it must be with a flux that is composed without either of these ingredients; or if they do enter the composition, it must be in very small proportions.

Composition of a softer flux for common purposes, where

the glass may be found too hard, N° 2.—Take of the glass of lead one pound; of pearl ashes, five ounces; of borax, five ounces; and of arsenic, half an ounce. This flux is suited, by its softness, to be mixed with colours that are to be used in glazing over others, where a harder flux has been used, and in most cases, where burning the colours with a slight heat is advantageous.

Composition of a flux perfectly pellucid and very soft, N° 3.—Take of common flint glass, powdered very fine, seven ounces; of borax, one ounce and a half; of pearl ashes, two ounces; and of sea-salt, one ounce. This flux, by its softness and clearness, will be found very useful for the oxyds of gold and silver; likewise in all cases where a tinge in the flux might be detrimental to the colouring substance that is to be used.

These fluxes, in the proportion here given, have been found to answer the purposes for which they are intended extremely well; but as the ingredients sometimes vary in their quality, it is evident that much must at all times be left for the ingenuity of the operator to supply. Indeed, when the difficulties that every person must meet with in attempts of this nature, without a previous knowledge of chemistry, are considered, we cannot do better than advise a study of that science as an introduction to the art of enamelling and enamel painting, by which means a complete theory of the various substances may be obtained, which, in the course of practice, may lead to useful discoveries; or, to say the least, will many times prevent useless experiments being made.

We must not omit noticing in this place, that dial-plate enamellers found great inconvenience in the loss of the Venetian white hard enamel, as that substance was principally used for the bottoms or backs of dial-plates manufactured of the English glass enamel; for the expansion of these two substances so exactly suited each other, that it was very rare that any of them cracked in the fire. This, however, was not the case with all the kinds that were brought from Venice, and particularly a blue sort, stamped on the cakes with the figure of a monkey, and commonly called monkey-enamel. This sort was very apt to crack the plates in circles, after they had been made a few weeks, unless it was used in composition with other substances, whose fluxes, being softer, contributed to counteract this disagreeable property.

These observations tend to confirm what we have before stated respecting the necessity of laying flux for grounds on hard enamel, because the English glass enamel, being much harder from the nature of its composition, does not run into fusion with the same heat as the flux; consequently a perfect adhesion cannot take place between these two substances. For a further account of the proportions of flux used in enamel colours, see *PAINTING on Enamel*. Handmaid to the Arts, vol. i. and ii.

FLUX, in *Hydrography*, a regular, periodical motion of the sea, happening twice in twenty-four hours; wherein the water is raised, and driven violently against the shores.

The flux, or flow, is one of the motions of the tide, (see *TIDE*): the other, whereby the water sinks and retires, is called the reflux, or ebb.

There is also a kind of rest, or cessation of about half an hour, between the flux and reflux; during which time the water is at its greatest height, called *high-water*.

The flux is made by the motion of the water of the sea, from the equator towards the poles; which, in its progress, striking against the coasts in its way, and meeting with opposition from them, swells, and where it can find passage, as in flats, rivers, &c. rises up, and runs into the land.

This motion follows, in some measure, the course of

the moon; as it loses or comes later every day by about three quarters of an hour; or, more precisely, by forty-eight minutes: and by so much is the motion of the moon slower than that of the sun. It is always highest and greatest in full moons, particularly those of the equinoxes. In some parts, as at mount St. Michael, it rises eighty or ninety feet, though in the open sea it never rises above a foot or two; and in some places, as about the Morea, there is no flux at all. It runs up some rivers above a hundred and twenty miles. Up the river Thames it only goes eighty, viz. near to Kingston in Surry.

Above London-bridge, the water flows four hours, and ebbs eight; and below the bridge, flows five hours, and ebbs seven. See *TIDES*.

FLUX, in *Medicine*, often called also *bloody flux*, the popular appellation of *Dysentery*, which see.

FLUX, in *Metallurgy*. All those substances which have been employed to facilitate the separation of metals from their ores, or to give greater fluidity in the fusing or soldering of metals, have by manufacturers been denominated fluxes.

Fluxes employed in separating metals from their ores have the effect of rendering the substances with which the metal is combined, capable of fusion. The whole is, by this addition of the flux, rendered fluid; the metal, being the heaviest fluid, sinks to the bottom; while the fluid mass, arising from the earthy matters of the ore, combined with the flux, floats on the surface: the latter, on cooling, puts on a vitreous appearance, and is, by manufacturers, called *scoria*. Hence it will appear, that the flux employed must be such a substance as may be best calculated to render those substances more fusible with which the metal is combined.

If the ore abounds with silex, potash or soda is best calculated to separate it from the metal. Tartar, which consists of the tartaric acid united with the potash, and frequently abounds with much vegetable matter, is employed to great advantage in the small way. The hydrogen and carbon present, take the oxygen from the metal; while the potash combines with the silex, forming a fluid vitreous mass, more or less coloured by the oxyd of the metal.

The substances known by the names of black flux and white flux are generally used in the smaller experiments. The former is made by detonating one part of nitre with three of tartar, so that it contains at least an excess of carbonaceous matter, which is fitted for the reduction of the metallic oxyd, while the potash, derived from the nitre and tartar, combines with the earthy products.

That called white flux, is formed by detonating equal parts of nitre and tartar, by projecting the mixture, by a small quantity at a time, into a red-hot crucible. In these proportions the whole of the carbonaceous matter of the tartar is destroyed by the oxygen of the nitre, and nothing more is obtained than a sub-carbonat of potash.

It will appear evident to every chemist, that common tartar, or for nice experiments, that super-tartaret of potash, will answer all the purpose of the black flux, and the sub-carbonat of potash be equally well taken for the latter. Some have recommended the nitre and tartar to be used together; but this will always be improper where the oxydation of a substance is intended. Nitre possesses a power so much the contrary, that it is capable of oxydating gold.

In the large way, on account of cheapness, lime is employed to separate the silex. Barytes, if it could be found more plentifully, might be used to more advantage for separating silex, particularly from iron ore.

Lime is found to be the best flux for smelting the alumi-

nous iron ores, from the great fusibility of due proportions of those two earths. Should the ore abound with silex, its reduction is found more difficult. It might be an advantage, where ores of this kind occur, to use some cheap compound of barytes, such as the sulphat of that earth.

From what has been observed, it will appear that it is of the greatest importance to be acquainted with the nature of the earthy matter in the different ores. Whether the ore contain alumine, lime, or both these substances, such a quantity of one of them should be added, as will make the most fusible compound of the two. If the alumine be in excess, lime must be added, but if the ore be calcareous, which is sometimes the case, it is found necessary to add clay. In the smelting of iron ores, however, the fusibility of the earths is much increased by the oxyd of iron, which always, more or less, colours the scoria. The oxyd of iron is found to exert a much stronger affinity upon silex than upon any of the other earths, and hence those iron ores abounding with silex, when smelted, afford more coloured scoria, and in consequence are less productive.

In the smelting of copper ores, which contain silex, it is common to add some substance which contains oxyd of iron; pyrites is generally used to afford this substance. But many copper ores contain iron, and need not the addition of this substance as a flux. The oxyd of iron combines with the silex, forming a dark coloured fusible compound, which floats on the surface, leaving the copper free from both those substances.

Most of the fluxes used in fusing or soldering those metals liable to oxydate by the presence of the oxygen of the atmosphere are such, as by fusing, when the metal would begin to oxydate, envelope the metallic surface, and prevent the combination of the oxygen. Of this class are many saline bodies, such as borax, pot-ash, soda, tartar, muriat of soda, &c. In short it should be such a substance as may fuse before the body becomes very hot. It should have no action upon the metal itself, and it should possess so much fixity as not to be volatilized by the heat required for the fusion of the metal. If the flux be at all liable to fly off, a fresh quantity should be frequently added.

Another species of fluxes act by reducing the oxyd as fast as it may be formed. The fusible metals are generally treated with those inflammable bodies, which combine with oxygen, with great facility, and at the same time involve the metallic surface. Rosin and fatty substances are mostly employed for lead, tin, antimony, and bismuth, or their alloys. Zinc requires to be treated in a close vessel with charcoal powder, or pounded pit-coal.

The vitreous and saline fluxes which act by preventing oxydation, are employed for cast iron, copper, brass, &c.

Pounded glass, or a mixture of lime and clay, may be employed for cast iron; pot-ash or tartar for copper and brass.

The scoria of blast furnaces is generally used in the fusion of steel which is to be cast into ingots. If too much of these fluxes be used, the firmness of the crucible will be endangered. Muriat of ammonia has a very peculiar property of freeing the surfaces of metals from oxygen. This has been explained, by supposing that the ammonia is decomposed; the hydrogen of which combines with the oxygen. This does not, however, clearly explain the fact, for the muriat of ammonia is not decomposed by this process, and much less by the ammonia. It is well known to those who manufacture this muriat, that if any metallic oxyd be present when this salt is sublimed, the oxyd rises with it, form-

ing a triple salt. Indeed the substance, known in medicine by the name of *floria martialis*, is formed in this way, and is a triple muriat of iron and ammonia.

The great utility of this salt in the soldering of metals, therefore, consists in carrying off the oxyd from the surface, at the time it sublimes.

Rosin and fat substances used in solderings give great fluidity and brightness to the solder, and clear the surfaces to be united, by their carbon and hydrogen taking the oxygen which may be present.

The flux employed for soldering iron, brass, and copper, are generally borax, (sub-borat of soda.) After the solder and the surfaces are once made clean, this borax acts, by preventing oxydation, till the solder fuses, and unites the two surfaces.

That this is the true explanation of the action of a flux, in soldering, we have abundant proof, in soldering one noble metal with another. When fine gold is employed for soldering platina, the gold is observed at the time of fusion to assume a degree of fluidity far superior to any solder made of oxydable metals, although the latter be assisted with the best flux.

In the fusion of those metals liable to oxydate, whether the fusion may be for the purpose of soldering or casting, certain fluxes are found to be indispensable. The fluidity is so much improved, that in the latter process, without a flux, the solder would not be able to run between the surfaces to be united, independent of its action in preventing the oxydation of the surfaces. In the casting of metals, the fluidity would sometimes be so imperfect, without the presence of the flux, that impressions taken from the mould would be exceedingly defective, and small articles, such as needles and fish hooks, could not be cast at all.

We shall conclude this article by giving a short explanation of the cause of increase of fluidity by the agency of fluxes.

Although an idea is entertained by chemists, that there is no medium between that pulverulent state called the oxydated and the metallic states, it will be found that the oxydable metals combine with oxygen when exposed to the air in a state of fusion, without losing their metallic form. They however lose much of their lustre and fluidity. Of this fact we have a striking proof in silver, which in the act of refining has been long exposed to a current of oxygen for the purpose of freeing it from the baser metals. At the time the silver assumes the solid form, the oxygen is given out in the form of gas. Mr. Lucas, a refiner of Sheffield, by throwing the liquid silver into water, collected an abundance of pure oxygen gas.

The partial loss of lustre and fluidity from the combined oxygen, is soon very apparent in melted zinc, both of which may be completely restored, by treating it in a close vessel with charcoal powder. All the oxydable metals are more or less susceptible of this change, proportionate to their affinity for that substance.

From what has been observed we may infer, that it is highly injudicious to expose much of the melted surface of metals to the air. Hence the iron ladles used for the fusible metals, as well as crucibles, ought to be as narrow as possible at the top, at the same time that some substance should be employed, which will either prevent the oxydation, or reduce the oxyd as it is formed.

FLUXES, in the *Manufacture of Glass*, are red-lead, pearl-ashes, nitre, sea-salt, borax, arsenic, the scoria of forges, commonly called clinkers, and wood-ashes. See GLASS.

Fly

FLY, in *Mechanics*, is an apparatus employed to equalize and regulate the velocity and power of many machines which require such regulation from the inequality either of the moving power, or of the resistance it has to overcome. A fly acts upon the principle that any body, being put in motion with a certain velocity at a certain expence of power, will continue to move until its motion is stopped by a resistance equal to its momentum or sum of the power and velocity which first caused its motion. This principle is carried into effect by various forms of the apparatus; the mass being generally made to revolve upon a centre, and the parts on the opposite sides of the centre being balanced. Two, four, or any other number of equal weights, placed on the opposite ends of arms or radii which are affixed to an axis, constitute a fly. If the weights be supposed to touch each other, or a hoop or ring of one piece be substituted, its form will be much improved; and it is now termed a fly-wheel, and is the manner in which the fly is most generally used.

The friction or resistance which the air opposes to any body in motion, and the friction of the pivots which support the axis of a fly-wheel, are considerable deductions from the power communicated to it; so that instead of a fly-wheel gaining power, as some imagine, it requires a constant exertion of power to keep it in motion, even when no other resistance is applied to prevent it. For this reason a mechanic should never introduce a fly-wheel into a machine, unless the advantages to be derived from its action are greater than the actual loss of power it occasions. As an instance, we will suppose a heavy stamper or hammer to be raised by a water-wheel; the action of the water upon the wheel is constant and uniform, and whilst the machine is lifting the hammer, this action is nearly balanced; but the instant the hammer falls, the principal resistance or load to the water-wheel is removed, and the water urges it rapidly forwards, until it meets the hammer again, when it is suddenly checked, and moves with diminished velocity, until it again loses its load. In such a case as this the fly-wheel is of great service, for in the interval while the resistance to the water-wheel is not in action, it prevents its acceleration, the power of the water-wheel being employed to give a momentum to the fly-wheel; and as soon as the velocity of the water-wheel is at all diminished, by the return of its load, the momentum of the fly acts to carry it forwards, and continue the motion with the same velocity until the momentum is expended in assisting the water-wheel. By this time the hammer has fallen, and the water-wheel left at liberty to communicate a new impulse to the fly.

In this, and many other similar cases, the power expended in giving motion to the fly is trifling, compared with what it preserves from complete loss during the interval in which the resistance of the water-wheel is inactive. If the water-

wheel had been applied to raising a stamper, the equalization might have been made by using three or four stampers in place of one, and adapting the machine to raise them successively: by this means, the load being divided and applied continually, the motion would be rendered nearly as uniform as by a fly-wheel, and without its inconveniences.

In this manner in many machines where fly-wheels are introduced, they are not absolutely necessary, saw mills, pump mills, &c., where a single machine which only acts in one direction is to be moved, all these might be improved by dividing the load, and causing its parts to act in succession; and for pump mills the double acting pumps may be used to great advantage, in lieu of a single one with a fly-wheel.

It is a great object in constructing flies to form them so as to present the smallest resistance to the air. For this purpose a wheel should always be used; the ring should be smooth and truly circular without any projecting nuts, &c.; the radii should be made to present a thin edge to the air, and the whole should be made of metal, that the greatest weight may be contained under the smallest surface; and for this purpose, if the section of the ring is a circle, the smallest surface will be exposed to form a resistance to the air, the radii should be of an elliptic figure, the narrowest edge meeting the air. This form of a fly-wheel is used by Messrs. Murray and Wood of Leeds in the steam engines which they erect, and is included in a patent they have for steam engines, and though they may have been the first who applied it to steam engines, the idea is not original, as Mr. Sully gave that form to his watch-balances many years ago.

A fly-wheel should be cast in one piece of metal, if it is not too weighty; in which case, the pieces of which it is composed should be melted together in the most solid manner imaginable, lest the centrifugal force of such a large mass, moving with a considerable velocity, should endanger the separation of its pieces. If by any accident the bolts connecting them become loose, or are weakened by rusting, (this failure, which has some times happened, is truly dreadful,) the force with which a fragment of the wheel is projected is irresistible; and if it should chance to strike the walls of the building, it would be in danger of total destruction. A method has been lately introduced of putting fly-wheels together, by dove-tailing instead of screw-bolts. The arms are fastened into the ring, and the segments of the ring fastened together by a system of dove-tails, which only admit of being put together in one direction, which is contrary to that in which the centrifugal force acts. Precaution on this head will not appear useless, when it is considered that fly-wheels of 8 and 10 tons in weight in the ring and arms are common in the machinery used for the manufacturing of iron, and their circumference moving at the rate of 300 feet per minute. We have seen one applied to a steam engine of 16 tons in weight, and moving much quicker. The ring is usually in six pieces, of

about a ton each, and connected only by a few wrought iron bolts as it revolves. The weight of these pieces, constantly acting in new directions, independent of the centrifugal force, is a severe strain upon the bolts and parts forming the connection.

The mode of calculating the size, weight, and velocity of a fly-wheel, proper to regulate the motion of any given piece of machinery, must be very intricate; though it is not usual for practical mechanics to employ calculation, their fly-wheels being adopted from the proportion of some other similar machine, which is found to answer its purpose. This subject has not been investigated in the elementary works on mechanics that we have seen; though, from its great practical utility, it would well repay the labour of any competent analyst, who would turn his thoughts to the subject.

The fly-wheel only acts when the velocity of the machine is variable: for having naturally a tendency to preserve an uniform velocity in itself, it will tend to move the machine connected with it in the same manner. On this account, it would be absurd to employ a fly-wheel in any machine where the power and resistance are always uniform, or bear the same proportion to each other: hence the motion of any machine, deriving assistance from a fly-wheel, cannot be perfectly regular, as it is only when a change in the velocity of the machine takes place that the fly-wheel has any action, and the power it exerts to continue the motion is greater or less, as the change in velocity of the machine is more sudden or slow.

In rolling mills, where the power which will be required is not to be estimated, and at the same time the resistance to the mill is not in action, a great proportion of the time, a large and heavy fly-wheel is necessary; in this case it acts as a collector of power. If the workman has an extraordinary large piece of metal to be rolled, he suffers the mill to work without obstruction a few revolutions of the water-wheel, that the fly-wheel may acquire such a velocity as will overcome the resistance to be opposed to it, which is perhaps far beyond the power of the mill to accomplish without such aid.

The coining press, or fly-press, is another example of the same sort. The momentum of a fly, put in motion by a continued action of several seconds, is expended in an instantaneous stroke upon a piece of metal, acting with astonishing power. The sledge hammer may be instanced as a similar case. The power given to the hammer in a certain space of time, is exerted in an infinitely short time, and with proportional power.

In all cases where the moving force is variable, a fly-wheel must be added, unless the resistance can be adapted to vary in the same degree. A man, turning a winch by his hand, or a crank by his foot, can exert three times the power in many positions which he can in others, particularly in the latter case: a fly-wheel is, therefore, of essential service, and the rotative motion obtained from the steam engine is wholly dependent on the assistance of the fly-wheel.

The fly may be applied to several sorts of engines, whether moved by men, horses, wind, or water; and is of great use in those parts of an engine which have a quick circular motion, and where the power or resistance acts unequally in the different parts of a revolution. In this case the fly, without adding any new force, becomes a moderator, making the motion of revolution almost every where equal and uniform: thus the engine becomes more easily and conveniently acted upon and moved by the impelling force; and this is the only advantage obtained by the fly. The best form of this appendage to machines is that of a wheel

or circle, of a proper size, as this will not only be less resisted by the air, but by being continuous, and the weight every where equally distributed through the perimeter of the wheel, the motion will be more easy, uniform, and regular. In this form, the fly is most aptly applied to the perpendicular drill, which it likewise serves to keep upright by its centrifugal force; as also to a windlass or common winch, where the motion is quick; for in pulling upwards from the lower part, a person can exercise a greater power than in thrusting forward in the upper quarter; when, of course, part of his force would be lost, if it were not accumulated and maintained in the equable motion of the fly. Hence, by this application of force, a man may work all day in drawing up a weight of 40 lbs. whereas 30 lbs. would occasion to him greater labour in a day without the fly.

The force of a fly, when joined with the screw, for stamping the image upon coins, may be calculated thus; suppose its two arms to be each fifteen inches long, measuring from the centre of the weights to the axis of the motion, and the weights to be fifty pounds each, and the diameter of the axis pressing upon the dye to be one inch; if every stroke be made in half a second, and the weights describe an half circumference, which will in this case be of four feet, the velocity will at the instant of the stroke be at the rate of eight feet in a second, and, therefore, the momentum eight hundred; but the arms of the fly being as levers, one brachium of which is fifteen inches long, whilst the other, viz. the semi-axis, is but half an inch, we must increase this force thirty times, which will give twenty-four thousand; an immense force, equal to that of a hundred pound weight falling a hundred and twenty feet, or near two seconds in time; or to that of a body of seven hundred and fifty pounds, falling 16 $\frac{1}{2}$ feet, or one second in time.

Some of these engines for coining crown-pieces have the arms of the flies five times as long, and the weights twice as heavy as those here mentioned, so that the effect is ten times greater. Desaguliers' Exper. Philosoph. vol. i. p. 245. 339.

Besides the utility of fly-wheels, as regulators of machinery, they have been employed for accumulating or collecting power. If motion be communicated to a fly-wheel by means of a small force, and if this force be continued till the wheel has acquired a great velocity, such a quantity of motion will be accumulated in its circumference as to overcome resistances, and produce effects, which could never have been accomplished by the original force. So great is this accumulation of power, that a force equivalent to 20 pounds, applied for the space of 37 seconds to the circumference of a cylinder, 20 feet diameter, which weighs 4713 pounds, would, at the distance of one foot from the centre, give an impulse to a musket-ball equal to that which it receives from a full charge of gun-powder. In the space of six minutes ten seconds, the same effect would be produced, if the cylinder were driven by a man who constantly exerted a force of 20 pounds at a winch one foot long. This has been demonstrated by Mr. Atwood in his "Treatise on Rectilineal and Rotatory Motion." This accumulation of power is exemplified in the Sling; and also in the machine for coining, as already stated. Messrs. Watt and Boulton have employed a new kind of fly, called the "Conical Pendulum," for regulating the admission of steam into the cylinder of the *STEAM-engine*, which see.

Notwithstanding the great advantages of fly-wheels, both as regulators of machines, and collectors of power, their

utility wholly depends upon the position which is assigned them, with respect to the impelled and working points of the engine. This position depends altogether on the structure of the machinery. It may be observed, however, in general, that where fly-wheels are employed to regulate machinery, they should be near the impelling power. And, when used to accumulate force in the working point, they should not be far distant from it. In hand-mills for grinding corn, the fly is for the most part very injudiciously fixed on the axis to which the winch is attached. It should always be fastened to the upper mill-stone, so as to revolve with the same rapidity. In the first position, indeed, it must equalize the varying efforts of the power which moves the winch, but when it is attached to the turning mill-stone, it not only does this, but contributes very effectually to the grinding of corn. Ferguson's *Mechanics*, by Brewster, vol. i.

FLY-press, an instrument of most extensive use in many manufactures for stamping or cutting small articles in metal. It consists of a chissel, punch, or cutting-tool, moved by a screw, which is furnished with weights acting as a fly. When these are turned rapidly round, the tool exerts an immense power on any substance subjected to its action. The press is often used without the fly, and is still called, though improperly, a fly-press.

Figs. 1, 2, 3, and 4, of Plate XXVII. (Mechanics) represent a fly-press with its minor parts, such as is in common use in Sheffield in a variety of manufactures, which we shall enumerate in their proper heads. *AA*, *figs. 1 and 2*, is a massive frame of cast-iron, of the dimensions expressed by the drawing and scale annexed. In the upper part of this frame a female screw, or screw-box is fitted, and the screw *B* passes through it. The top of the screw is fixed to a curved handle *a b c*, furnished with a heavy weight *c*, which acts as a fly, when the handle is turned round by a workman sitting before a bench or table, on which the press is fastened by two bolts passing through projecting pieces, *d, d*, of the iron frame. At *e* a piece of iron is fastened, projecting from the iron frame, and supporting a socket for the square iron slider *f* to slide up and down through, and to avoid any shake in its motion. The socket can be at any time made to fit the slider by the four screws (seen in both figures) which draw the two halves of the socket together. The upper end of the slider *f* is connected with the screw *B*, by a joint which allows the screw to turn round independent of the slider, but obliges the latter to accompany the screw in its vertical motion, either ascending or descending. At the lower end of the slider *f*, the punch or tool, *g*, is fastened by a clamp-screw: it acts in combination with another tool, *h*, called the die, fixed below it in the frame by four screws *i*, as shewn in *fig. 3*, which allow of its adjustment in the true position beneath the tool. The lower tool, or die, *i*, is fitted into a block, which is held by the four screws, and by this means the die can be quickly changed without disturbing the press. The upper tool can be removed in the same manner by releasing the clamp-screw which holds it in the slider *f*.

These, as the essential parts of the fly-press and its operation, are too simple to require much explanation. The workman, being seated before the press, holds the piece of metal to be acted upon in his left-hand, and draws the handle *a* towards him with the other: this, by turning the screws, forces the punch down upon the metal, and the momentum of the weight *c* causes it to act with such force, that the resistance of punching through a thick piece of metal is scarcely perceptible upon the handle. The principal part of this power is gained by the screw as well as by the accumulated *vis inertia* of the fly. For many purposes

where the resistance is but slight, the weight *c* is removed: the press acts simply by the lever and screw. It still retains, though improperly, the name of the fly-press. This alteration is intended to give the workman such a command of the machine, that he can more quickly reverse the motion than will be the case when the fly is in action. This can be only done where the resistance is very slight. Nails, the teeth of saws, open-work of fenders, and similar articles, are cut with appropriate tools in this manner. *Figs. 4. and 5.* represent some of the tools to be used in the press; *a* is a punch, and *b* the socket, or die, for perforating a circular hole, either with the view of forming a hole in a metallic plate for rivetting, &c. or to preserve the piece struck out for boat-builders rivets, washers, or collets, buttons, ornamental studs for fenders, and a vast variety of other purposes in which small circles of metal are useful. These pieces are forced through the die, and fall through a hole made in the frame *A*, into a small drawer placed beneath the bench for their reception.

C, D, are another pair of tools, in which the die *D* is embossed to the shape intended to be impressed on the ornamental studs cut by the former punch. These are forced into it by the flat surface of the upper tool *C*. In some cases this tool at the same time punches a small hole by which the stud is to be rivetted to the article it is intended to ornament, and the die must then be perforated with a small hole to convey away the fragment of metal forced out by the punch. In many cases these studs are intended to be fastened on by a small pin projecting from their lower surface: in this case they are forged or cast in the manner of a nail, and the point or shank of a stud being inserted into a hole. In the lower die the upper tool is forced down upon it, and imprints its figure upon its head: it is plain that here the upper tool must be embossed instead of the lower. A concave or convex figure is given to the small circles before-mentioned, by making the end of the punch *a*, *fig. 4.* concave or convex, and the pressure it exerts to force out a piece of plate is sufficient to impose upon the fragment the figure of the punch. In *fig. 5.* *E, F* are another small pair of dies for punching small circular holes, and *G H* is a similar pair of tools for square holes.

The manner of punching out the concave shells for small buttons, which are termed *shell buttons*, is deserving of notice. First, small circles, (one of which is seen in the section at *r*, *fig. 6.*) are cut out from plate-brass, by a plain round punch and die, similar to *a b*, *fig. 4*; the dies, (*fig. 6.*) are now used. The circle of brass, being placed over the hole of the die *L*, is forced through it by the end of the other tool, *K*, which being smooth and of a spherical figure, causes the plate of metal to assume the same form, and fall into the drawer beneath in the state of *s*, when it is fit for use. It must be observed, that the aperture through the die, *L*, is as much larger than the tool *K*, as to admit the thickness of the metal all round it, and the upper side of the whole must not be left sharp, but rounded off, so as not to cut, but only bend the piece of metal in passing through it: also the circle of metal must be larger than the hole, that there may be a sufficiency to form the cup or hemisphere *s*. The size of this circle is shewn by the dotted circle *r*, in the plan *fig. 6*, which likewise shews a piece of brass *t*, in the form of a square; it is fastened upon the die, to guide and stop the circle in the point where it is concentric with the hole over which it is placed.

The open-work in fenders, and ornamental fire-grates, is stamped out by the fly-press. For this purpose the pattern

intended to be cut out is described upon the plate of cast-steel intended to form the fender, and by appropriate punches the holes are successively cut out. In this manner the diamonds, lozenges, triangles, and other figures, we observe in these articles are removed with great facility. This operation has lately received great improvement from Mr. Proctor of Sheffield. By this new method a great number of punches, and of different figures, are moved at the same time, and the necessity of describing the pattern upon the plate is obviated; whereas in the common method the fenders must pass through the prefs as many times as there are figures in the pattern, and it requires some skill and judgment in placing the fender so correctly in its true position beneath the tool of the prefs, as to have no inaccuracies in the pattern discernible to the eye.

Fig. 7. is the prefs used for the purpose, though not exclusively, all heavy articles being stamped in a prefs of this kind. The improved apparatus is seen on the ground by the side of the prefs, where *AA* is the piece of steel plate, inclosed between two leaves of a frame *B*, similar to book-lids. The leaves are two plates of steel, hardened and tempered; the figure of *D* (fig. 8.) cut out in exactly the same pattern as the fender is intended to be. These plates are attached, by four screws in each, to an iron frame *B*, connected by hinges *E*; when shut together, as at *AA*, the apertures in the upper and lower leaves correspond, and the plate *A* is interposed between them. A number of steel punches of the proper figure, as *F*, are placed in the holes of the upper leaf, so as to fill them all up, and the whole is placed upon the lower bed *H* of the prefs, and the flat iron bed *I* being forced down upon the punches by the screw, drives them all through at once, and removes corresponding pieces from the steel plate *AA*. The punches fall through the plate, and are received in a small drawer, beneath the bed of the prefs. The screw being turned back, the tools and plate are removed to the table *K* before the prefs, the book opened,

and the plate is put forwards through the leaves, so as to cut out another length. To ensure the parallelism and proper distance from the former pattern, the leaves have one more hole in them than is intended to be cut out at the operation. In fig. 8. *a* represents this hole, which is brought to coincide with the hole cut by *b* at the former operation. By this means, it is certain to be in a straight line, and to keep it so. A punch is put through the plate in this hole *a* before it is placed under the prefs a second time. The workman is seated upon the beam *L*, before the table *K*, and finds the punches, which had fallen through into the drawer, standing up in it in the true position; and he has only to transfer them to the leaves for the next stamp. At *N* is shewn another pair of leaves; and at fig. 9. a piece of the plate cut between them: *n*, are two of the punches; the leaves are represented as opened to admit the plate, and its position is adjusted by passing two of the punches through the holes stamped in the plate by the former stroke.

The prefs (fig. 7.) is of large dimensions; its frame *P* double to give greater strength; the lever *R* loaded at each end with heavy weights. It is many feet in length, though it is seen endways, and consequently foreshortened in the drawing. The frame *SS L* is placed beneath the surface of the ground, and a circular walk is made for the two men who run round with the end of the lever *R*, to give it as great a velocity as possible, that its momentum may give a great energy to the action of the screw. The workman seated upon *L*, is low enough to be beneath the lever as it moves over his head. The screw is pointed at the lower end, and acts in a socket on the top of the slider *M*; to the lower end of which the moving bed *I* of the prefs is fastened; to balance the weight of the slider and bed, a lever *X*, and a heavy weight *Y*, are applied, which raises them up when the screw is turned back, so as to admit the work being placed beneath the prefs.